PHOTO-MEZZOTINT

Reproduction of Photograph by Levy's new Photo-Intaglio Process

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A NEW PHOTO-INTAGLIO PROCESS.

BY LOUIS E. LEVY.

[*Read at the stated meeting of the Institute, held September 21, 1892.*]

JOS. M. WILSON, President, in the chair.

MR. LEVY: With the exception, perhaps, of the domain of electricity, there is no other special field wherein the recent advances of science have opened so many avenues of progress and effected such notable changes as in the range of the graphic arts. From the time when, fifty years ago, the earlier researches of Scheele and Seebeck on light-sensitive compounds were first wrought into practical shape by Niepce, Daguerre and Talbot, the applications of photo-chemistry have increased in number and extent to such a degree that to-day the various processes of photographic reproduction would require a long catalogue to merely name them. Many of these variations, though marked, are

unessential; others have proven of scientific interest only, while quite a long list of practical photo-reproductive processes have from time to time been superseded by simpler and more efficient methods.

The new photographic process which I have the pleasure of announcing to the Institute this evening is, as I trust will appear in practice, an effective and greatly simplified method of producing a photographic reproduction in the form of an intaglio engraving. Such engravings, technically known by the French term "photogravure," have been produced for some years past by a variety of photo-chemical processes, the most notable of which are those wherein the result is attained by means of a chrome-gelatin film. The fact that a film of chrome-gelatin becomes insoluble when exposed to light, and remains more or less soluble according to the degree to which light is permitted to act upon it, has been made the basis of a variety of processes for the production of photo-engravings. The gelatin film long served as the most effective means for the production of photo-engravings in relief, and still furnishes the basis for the production of photo-engravings in intaglio. For both purposes the sensitized gelatin film is exposed under a transparent negative or positive, as may be requisite in the subsequent procedure; the unaffected portions and unreduced quantities of the exposed film are either swelled by absorption of a liquid or are dissolved and washed out, and the film then dried. In this condition it may be printed from direct, or it may be used as a mould to produce a reverse in a fusible metal; or it may be covered with an electrolytic surface to receive an electrotype deposit, or it may be moulded in plaster, wax, gutta-percha or other suitable substance, from which, in turn, a reverse can be made by casting or electrotyping. Intaglio photo-engravings have also been produced by a process wherein the varying amounts of reduced silver left in the developed gelatino-bromide plate are made to serve as a corrosive or etching agency on a plate of copper on which the bromide plate is imposed, but in general practice the washed-out gelatin film has thus far proven the most practical means to the desired end.

In all photo-intaglio processes hitherto known or practised, the nature of the plate produced and the end sought to be attained is akin to that which is technically known as a mezzotint or aquatint engraving. The essential feature of such engravings consists of the varying depths to which the design is sunken in the plate, the graduations of depth in the plate corresponding to the gradations of light and shade in the printed impression. The ink being rubbed into the depressions of the design and rubbed off from the surface of the plate, the highest parts of the engraving represent the highest lights of the design, the deepest depressions render the darkest shadows and the intermediate depths produce the half-tone gradations of the picture.

The difficulties attending the production of photogravure plates with the particular degree of graduation of depth which is requisite for an artistic effect in the printed impression are such that the process is practised only by a few, the skill and experience needed for the work being attained only after a long practice and then in a full measure only by such individuals as possess artistic capacity and training. In only one establishment, and that in Paris, has the work been brought to a high degree of quality, and there, as well as in other workshops, the hand of the skilful retoucher is frequently to be credited with the largest share in the final result.

To free this result as far as possible from the limitations of human handiwork, and to bring it forth under the more uniform and definite control of scientific procedure has been my aim in the experiments which have resulted in the present method. This method I have named "Photo-Mezzotint," not because that is the most exact term by which to denote it, but because all the other good names have already been pre-empted and made to do service in other directions.

The essential feature of the new method lies in the fact that the picture, instead of being obtained from a graduated depth of the engraving, is produced from a sunken surface of uniform depth, the gradations of light, half-tone and shade being effected by minute lines and stipples of

varying thicknesses but of uniform distance apart from centre to centre. In this respect the photo-mezzotint may be regarded as a development of the so-called half-tone relief process, the true mezzotint or photogravure effect being attained by reducing the thickness of lines and stipples and multiplying their ratio to the surface to such a degree as to render them invisible to the naked eye. In that way all the finest gradations from pure white to deep black are obtainable, with the result shown by the specimens before us. In these the picture is made up of equidistant stipples, varying from a microscopic point up to a size where they coalesce into a solid black, the half-tones consisting of stipples of about one four-hundredth of an inch in diameter, and about 44,000 to the square inch. If a coarser stipple is used the effect varies from that of a mezzotint and approaches more nearly that of a line engraving, the lights and shades being made up of perceptible lines and stipples, like the effects of a steel or copperplate engraving of equal texture.

The processes at present in vogue for the production of photo-intaglio plates require not only long experience and a high degree of manipulative skill, but also take up quite a length of time—frequently a week or more--for their completion, and the plate, after passing the stages of the photochemical process, has then still to be extensively helped by the work of the retoucher. The retouching of photogravure plates inevitably introduces a degree of uncertainty as to the accuracy of the reproduction, the result as left by the retoucher being frequently very different from the original in its disposition of lights and shades. By this new process all these undesirable factors are eliminated; its manipulations are far more facile, the length of time for the entire work is reduced to a few hours, and the result is complete without the supplementary aid of the skilful engraver, except, possibly, in cases of local blemishes or accidental defects. It is therefore reasonably to be assumed that this new method of intaglio engraving, which has been made the subject of an application for letters-patent, may be regarded as a desirable addition to the category of the graphic arts.

SHIP CANALS.

By Prof. Lewis M. Haupt, Consulting Engineer.

[*A lecture delivered before the Franklin Institute, November 4, 1892.*]

Mr. President, Ladies and Gentlemen:

From Adam to Noah, from Noah to Columbus, from Columbus to Peary, navigation has allured mankind by her charms of adventure and discovery, to thread the labyrinths of continents, and to plough the trackless oceans until the mythical "*Ne Plus Ultra*" of the fifteenth century has become the reality of the nineteenth.

Nor is it surprising that there is so little left to discover when it is remembered that the reward is so great, resulting in the possession, by the discoverer, of the new territory with its hidden resources and boundless wealth.

It does not require any great effort for fleet-footed fancy to span the 400 years which have passed, as a tale that is told, and picture to ourselves a little convoy of three small vessels, manned by a courageous crew of 120 men and their inspired commander,* battling with the waves and currents of the interminable ocean, all to prove the theory that the earth is round, by sailing west to reach the East.

On the twelfth of October, 1492, the theory was verified, and an impetus was given to the Star of Empire which has since outdone Puck himself in girdling the earth.

Transportation has opened the storehouses and granaries of the world and has so knit together the kinship of mankind that famine is allayed, disease abated, poverty relieved, employment furnished, knowledge disseminated, the savage tamed, the heathen civilized, and the race ennobled through its benign influences.

Transportation is the chain which binds together the humanity of the globe. It is composed of distinct yet dependent links, any one of which being broken impairs the

* Sailed from Palos August 3d, and on October 12, 1492, sighted land.

bond and reduces the efficiency of the whole. The three principal links are waterways, railways and highways. The auxiliary, yet all important adjuncts are the submarine cables and electric conduits, so useful in regulating the operation of the primary conductors. There are many minor sub-divisions, useless to follow in this connection, but it is of importance that a comprehensive view be taken of the relations existing between the three parts of the great system of transportation. There is a prevailing opinion in railroad circles, that the waterways are injurious to their interests, since they can carry freight in bulk at much lower rates, but, paradoxical as it may seem, I believe it is abundantly proven by statistics that such impression is erroneous.* The railway occupies an intermediate position between the water and highway and is dependent upon both for receipts and delivery of a large part of its traffic. But, for this evening, our attention is to be directed to that one phase of the waterway known as the "SHIP CANAL."

The efficiency of any line of communication, whether on land or water, is increased by reducing its resistance and augmenting its tonnage, and this is especially true of waterways, where a short cut of a few miles may often save hundreds or even thousands, as in the case of the Suez and Nicaragua; while the traffic using such channels is a function of their depth and sectional area. It is evident that if the vessel draw more water than that furnished by the canal it is debarred from transit and a large part of the tonnage and revenue is excluded. Hence the great importance of deep draft waterways. In fact their commercial value is estimated to increase *as the cube of the depth*, so that by merely doubling the depth the value is increased eight-fold. Wherever there is a peninsula which separates navigable waters of any magnitude, there will be found an opportunity for reducing the length of a route, and for economizing in transportation. The percentage of distance saved, with the amount and character of the traffic, are the principal factors

* See in *Engineering Magazine* of March, 1892, a paper entitled, "Do Waterways benefit Railways?"

in determining the expediency of constructing a canal, but there are many subordinate elements entering into the problem.

It should be borne in mind that water, although a public medium, is non-productive of freights, if we except ice and fish, and yet it occupies five-eighths of the globe, hence the distance traversed are relatively large and the rates must be comparatively low. That this requirement is wisely satisfied in the physical world will appear from the following considerations:

Water and air being fluids offer less frictional resistance to bodies passing through or over them than the solid substances in contact in land transportation. Water at rest is also level, having no grades to be overcome, while the undulations of a highway or railroad require every pound of freight to be lifted vertically at great expenditure of power, for which there is no useful return.

Every change of direction on a railroad increases the friction, as well as the distance between terminals, while it reduces the efficiency of the motor, whereas the vessel on an open sea may select the shortest course between ports of clearance and entry. The efficiency of the marine engine is also about seven times greater than that of the locomotive at ordinary freight speeds.

Moreover, the capacity of a vessel is much greater than that of a car or even a train of cars, while its cost per ton of dead load is generally less, and its life is longer. Thus a canal boat of 190 tons would carry as much as seven of our largest freight cars, while an ocean tramp of 3,000 tons would require 110 cars with their engines.

The facilities for loading are frequently greater in the case of ships than of cars, and the time required for an equal volume less. In short, from whatever point a comparison be made, the advantage would seem to be on the side of the water borne commerce. The best criterion, however, will be found in the cost of movement; for example, in 1868 the lake and canal system from Chicago to New York was charging 22·79 cents, as against 42·6 by rail for the same service. Ten years later the water rate had fallen to 9·15 cents as

compared with 17·7 cents by rail. In 1885, the relative rates were 5·87 and 14·0 cents, while in 1891 they were 5·96 and 15·0 respectively, or the water rate was only two-fifths of that by "all rail."

In fact, notwithstanding the great improvements in railway transportation, and the apparent neglect of canals, the latter have been able to maintain their supremacy so far as the cost of movement is concerned; but the purchase of the canals by hostile management and the systematic solicitation of business by the railroads have seriously crippled the canals without economizing for the benefit of the public.

The cost of carriage by ocean or lake vessels on an open waterway is so low as to be hopelessly beyond railway competition. These rates are but a small fraction of a mill per ton-mile, or about one-twenty-fifth of the lowest rail rates—and explain why it is that the overland tonnage makes a bee line for the nearest deep water channel, and why the proper location for commercial cities is at that point farthest inland which can be reached by ocean vessels. It also serves to show the intimate, reciprocal relations existing between these two great systems of transportation:

"Useless each without the other,"

though they are not often so regarded.

In fact, when this was written, the Trans-Continental Railway Association was in session considering the propriety of a reduction on rates for east-bound freights over the Southern Pacific Railroad, because, as was stated, "the American clipper ships are carrying freight from San Francisco to New York around Cape Horn for $3.50 per ton, while the railroad charges $20, and the ships are getting most of the freight." At least, the railroads appeared to think so! Here is a difference of $16·50 a ton, which it is desired the consumer should pay to maintain a system of transportation which is much more expensive to operate than that provided by nature and without which much of the freight carried at the low rate could not be moved at all. It may be readily assumed that the transcontinental lines do not want the Nicaragua Canal completed, as it would reduce

the distance by sea between San Francisco and New York from 15,600 to 4,900, saving about 10,000 miles, and to Liverpool from 15,600 to 7,600, saving 8,000 miles. Yet this canal would so stimulate the commercial and industrial interests of the United States, both East and West, that I have no doubt the traffic of the transcontinental lines would be largely augmented, in accordance with the observed results of such improvements elsewhere. A fact which is worthy of note. The rate per ton-mile by the clipper ship around the Horn is almost microscopic, viz: $·00225, or about one-fifth of a mill, yet it leaves a fair margin for profit, and the proposition of the Southern Pacific to lower the rate shows either that their present charges are higher than they should be or that it is proposed to carry at or below cost to destroy, if possible, a public benefactor, when the rates will become higher than before.

This is illustrated in the case of the Schuylkill Navigation, which delivered coal forty years ago in this city for prices ranging from seventy to ninety cents per ton for freight. To-day, with the canal under railroad control, the rates for home consumption are more than doubled, and the canal still enters its silent protest, and is disfigured with the decaying evidence of its former greatness.

If there were a profit at seventy cents in former days, when operated by mules, what a handsome revenue could not its lessees secure at $1.80 if operated by the cheaper modern appliances? I believe this canal the most valuable piece of property belonging to the Philadelphia and Reading Railroad Company, if it were only operated to its full capacity.

But to return to the Nicaragua route and its effects on the clipper ships. If it save 10,000 miles each way at ·22 of a mill per ton-mile the total economy would be 64 per cent. and the rate would be only $1. 30 per ton, while as compared with the present rate the sailing vessel could pay $2.20 per ton toll and still more than double its revenue, as it could make more than twice as many trips. This would be equivalent to thirteen mills per ton-mile for toll through

the canal. Steamers could afford a much higher rate as their running expenses are so much greater.

As an illustration of what may be done in the way of reducing the cost of movement on a canal of ordinary dimensions, reference is made to the experience on the Aire and Calder Canal, of Yorkshire, England. It is now carrying steamboat trains of barges composed of ten to twelve boats of about forty tons capacity each. The boats are only 20 feet long, 16 wide and 7½ deep, and the cost of transporting coal on the thirty-five miles of this waterway is only one-sixth of a mill per ton-mile, the boats returning empty. Most of the English canals are of much smaller dimensions, having only 4 to 4½ feet draft. Of the canals in Great Britain, 1,238 miles are owned by the railways, while 1,403 are independent.

The relative expenses by rail and canal there, are as follows:

	Rail. Per Cent.	*Canal. Per Cent.*
Maintenance of way,	13	0
Maintenance of works,	7	2·3
Repairs of rolling stock,	19	6
Traction,	16	8
Traffic expenses,	30	6
General charges,	15	15
	100	37·3

Showing an economy of 64·7 per cent. by canal. When the railway fever was at its height in England, the general public neglected the canals entirely, but the railway companies bought up all they could obtain and "strangled the whole of the inland water traffic." Now, however, the public, through Parliament, are alive to the advantages of inland water communication, and will not permit any further extension of the power of the railway monopoly over the waterways of the country.*

In this country the air is now full of canals, but the air is not the place for them, they should be on the earth and in operation. Too much time has been lost in considering

* *Consular Reports*, 1890. Evan R. Jones, Consul to Cardiff.

them, while our neighbors over the border, knowing their commercial value, have already spent $54,000,000 in building and enlarging the system bordering the St. Lawrence and the Great Lakes, and in about another year the United States' railway and other interests will awaken to find the enormous lake traffic seeking distant markets through foreign channels, instead of through the shallow 350 miles of canal and 150 miles of partially-improved river, which separate Buffalo from New York. To compete with this system we should have the twenty-foot waterway from the lakes to tide-water, also the ship canals across New Jersey and Delaware to open up our Southern connections; the Lake Erie and Ohio Ship Canal to put us in communication with the rich and populous Ohio River basin, and the Illinois and Michigan Ship Canal to complete the Great Belt waterway to the Mississippi. The Florida and Cape Cod Canals are also important parts of the great system, while the climax is reached in the Nicaragua Canal for the commerce of the world. The economies it would effect are almost inconceivable and do not appear to be appreciated by the public.

There is no need to speculate on the prospective benefits of works of this class when history is replete with illustrations, and yet we are now repeating the experience of the most successful projects in the world. Take the Suez Canal for example, a work which has cost about $100,000,000, and yet pays large dividends. Only fifty-eight per cent. of this amount was expended in the work of construction proper. This project was opposed by the British government officially.

The Prime Minister in 1857 stated his reasons for his opposition. Robert Stephenson, the great English railroad engineer, reported that the canal was impracticable and that he was against it. The sentiment of many other Englishmen as well as of the press was hostile. The *Edinburgh Review* said it was "utterly impracticable" and urged that "the available population or resources of Egypt could not execute such a work in 100 years;" that the cost of maintenance would equal the original outlay; that vessels would

have to be paid to induce them to patronize it, if built; that it might be an interesting question to discuss but could hardly ever benefit mankind.

The *Quarterly Review* followed in the same strain—believing the scheme to be commercially unsound, etc. The effect of this agitation was that while England did not contribute anything to the building, it has since been the largest patron and the greatest beneficiary from its construction.

An English author* in referring to this condition of affairs, recently said:

"No one at that time could have foreseen that in less than thirty years from that date the Suez Canal would have become an accomplished fact, and would have become perhaps the most successful industrial enterprise of modern times; that it would have revolutionized our shipping and transit trade; and that our Indian and Australian possessions would have participated in its advantages to an enormous degree. Prescience of this kind is given to but few men."

Until then no suitable machinery for such work was available, most of the work had been done previously in rude Arab baskets. The total excavation exceeded 100,000,000 cubic yards, yet the work was commenced in 1859 (April 25th), and opened to commerce November 17, 1869, or in ten and a half years.

The company was incorporated December, 1858, with a capital of $40,000,000, divided into 400,000 shares, @ five per cent. interest to be paid during construction.

Of this capital England subsequently bought 176,000 shares, @ 113, recently quoted at $550, and on which twenty-three per cent. dividends have been paid.

The traffic on this canal has exceeded the most sanguine expectations, and the receipts for 1890 were $13,485,000.

In 1886, electric lights enabled the canal to be used by night as well as by day, and the traffic increased rapidly in consequence, while the average time of transit has been

* J. Stephen Jeans, *Waterways and Water Transport*, London, 1892.

reduced from thirty-three hours fifty-eight minutes to twenty-two hours nine minutes. The number of vessels passing through in 1890 was 3,389, carrying a net tonnage of 6,890,014 tons. Hence the average tonnage was 2,033 per vessel, the average charge $3,976. The distances and the tolls were fixed in the concessions at ten francs ($2) per "ton capacity" (an expression which gave rise to subsequent difficulties), and ten francs for each passenger. But these rates are prohibitory for the lower class freights, and hence more than forty per cent. of the Eastern trade is still carried around the Capes. In 1885, the rates were reduced to $1.85 per ton.

The trunk of this canal, 99·9 miles long, is only 72 feet wide at bottom, 196 at top, and 26½ feet deep, but the traffic has increased to such an extent as to justify its enlargement.

This single instance might suffice to point the moral, but general deductions cannot be drawn from special cases, hence I beg to call attention to a still more remarkable instance of the development of our national resources, due to increased transportation facilities, as illustrated in the SAULT STE. MARIE Canal, at the outlet to Lake Superior, which during the 226 days of navigation in 1890 carried 8,454,435 tons, at a cost per ton-mile of 1·3 mills.

Of this only four per cent. was carried in Canadian vessels, yet Canada is rapidly pushing a rival and larger canal to completion around the falls.

The "Soo" Canal, as originally built in 1856, cost $999,802.46. It was enlarged by the United States between 1870 and 1883 so that the lock might be 515 feet long, 80 wide and 18 deep at a cost of $2,171,000, and a second enlargement is now under contract which is estimated to cost $4,738,865, to result in a lock 800 feet long, 100 wide and 21 deep. The canal is only about one mile long and was transferred to the General Government, by Michigan, in 1881. The cost of operation and maintenance in 1890 was only $45,417.66.

Thus in the past decade the traffic of Lake Superior alone has outgrown the capacity of a lock, which, when it was built, was supposed to be adequate to meet all require-

ments for many years. It is therefore a very moderate estimate which places the traffic through the Nicaragua Canal at 9,000,000 tons. Upon this basis, and the reasonable average charge of $2.50 for the 169 miles, the revenue would be $22,500,000, or twenty-two and a half per cent. on the capital, while the canal would tap the commerce of the world.

There are so many ship canals in process of construction throughout the world that even to repeat their names and dimensions would become burdensome, but a few of these are deserving of mention for the sake of the argument and lesson which they impress. Among them may be mentioned the NORTH SEA AND BALTIC CANAL intended to connect the waters named in the title, whereby 237 knots will be saved, thus shortening the journey of sailing vessels by at least three days, and of steamers by about twenty-two hours, in normal weather. The tolls for this saving are fixed at the low rate of eighteen cents per registered ton. This channel will be 61 miles long, 85 feet wide at bottom, 196 at top, and 28 feet deep. There will be only two tidal locks. The heaviest cut is 98½ feet deep. The contract price in 1889 was twenty cents per cubic metre, but the machinery was not being worked to advantage as the ladder dredges then used were idle, while the cars were run off to the dump. In this case the length of the canal is about twenty-seven per cent. of the distance saved.

The AMSTERDAM SHIP CANAL is another illustration of a great canal constructed to reduce the distance to the sea, for although the North Holland Canal, eighteen and a half feet deep, furnished an outlet, yet the competition with Antwerp and Rotterdam was so severe that it became necessary to reduce the distance and increase the draft to accommodate the larger vessels coming into use. By this new line the distance was reduced from fifty-two to fifteen and a half miles, which is forty-two per cent. of the distance saved. The difficulties to be overcome by this canal were unusually great, but they have been surmounted, at a cost of $15,000,000, or about $1,000,000 per mile. This channel is eighty-eight and a half feet wide at bottom, and only twenty-three feet deep.

But time will not admit of an extension of this description of the many completed and successful ship canals to be found. These few have been cited as a basis of comparison for a projected work which I shall now describe and which presents exceptional facilities for construction and traffic. It is believed to be unrivalled in the results to be attained in proportion to the amount required to secure them. I refer to the short link known as the Chesapeake and Delaware Canal, which unites these great bays with their tributary territory, reaching almost to the Rocky Mountains.

The peninsula separating the "Mother of Waters" from the Delaware extends southwardly 175 miles from the narrow neck of land which the canal traverses, while the distance across is but thirteen and five-eighths miles. Prior to the railroad era, the importance of piercing this barrier and thus saving over 300 miles in the journey from Philadelphia to Baltimore by water was fully realized, and although the resources of the country were very limited, the population small and scattered, the facilities for construction very meagre and the work to be done great, our public-spirited ancestors were not deterred from undertaking it.

The canal company was incorporated by the Maryland Legislature in 1799, and work was begun in 1804, but little progress was made until after the completion of the Erie Canal in 1825, when Judge Benjamin Wright, who built a large part of this work, was appointed consulting engineer, and pushed the project so vigorously, that in September, 1829, barges were allowed to pass regularly through, and on October 17th it was officially opened with imposing ceremonies.

The magnitude of this undertaking at so early a date can scarcely be appreciated at this stage of applied science. In the "Deep Cut," which is nearly four miles in length and seventy-six feet deep at its highest point, there were 3,500,000 cubic yards of earth, which were removed and deposited beyond the sides of the cut, making the present height in some places 100 feet. There were difficulties from landslides and bottomless marshes, so that the excavation and fill

exceeded the original amount by over ten per cent., yet the entire work was rapidly completed at a cost of $2,250,000, or $161,000 per mile.

The general dimensions of the trunk of this original canal were the same as those of to-day, viz: 66 feet wide at the surface, 36 feet at the bottom, and 10 feet deep, while the locks were 100 feet long and 22 feet wide, but in 1854, or a quarter century later, they were enlarged to 220 feet in length by 24 feet in width, which dimensions they still retain, although much too small for the vessels of to-day.

There are two levels to surmount; the first extending from Delaware City, where there is a tidal lock of six feet lift, to St. George's, four and a half miles; the second reaches from St. George's lock, with its ten feet lift, to Chesapeake City, about nine miles. Here there is a single lock of sixteen feet descent into Back Creek, a tributary of Elk River, which in turn debouches into the bay.

The route passes through a rich agricultural country, and the channel is far from being a contracted ditch, such as the name canal generally suggests. With the exception of the pass through the defile of the Deep Cut, it is a succession of pools and broad streams, varying in width from a few hundred feet to nearly a quarter of a mile, and for a large part of the distance the tow-path does not conform to the sinuous banks, but winds gracefully along an embankment placed in mid-stream. These features are mentioned because they are peculiar to this line, and form exceptionally favorable conditions in the project of enlargement.

For sixty-three years this waterway has continued to perform a valuable service, but in the race for supremacy, and the expansion which has taken place in the capacity of vessels, it has gradually fallen to the rear, until now it may be said to be antiquated and unable to fulfill the purpose of its builders.

In 1871 a National Commercial Convention, assembled in Baltimore, memorialized Congress to make an examination for a ship canal across the peninsula, and in consequence surveys were made of eight different routes, with estimates for their construction ranging from over $41,000,000 to $7,-

605,471. This last was for the Chesapeake and Delaware route, with approaches extending all the way from Baltimore to the sea, and providing a channel twenty-seven feet deep, measured from mean low water, having 100 feet width at the bottom.

In making his report on this project, Col. Wm. P. Craighill, in referring to the present canal, said: "But this has neither depth nor width enough for the accommodation of steamers or sailing vessels designed to cross the Atlantic," and in speaking of its strategic value he observed: "It will be doubted by no one that a deep-water connection between the two bays would be of vast importance in the contingency of a war with a maritime nation;" also, "It may be assumed that if a war with one of the great naval powers should arise, and the mere appropriation of the money could provide such a channel of communication between the bays, the amount would be at once provided without hesitation. That would, however, be too late." For security of communication and defense this route is superior to any other. Thus its importance to the Government from a military point of view is conceded, while its value to the commerce of the seaboard cities, as well as the great West, is also manifest by the great economy which would result to transportation from such enlargement. The saving each way of 190 miles for foreign commerce and 330 miles for the coastwise, by a canal only fourteen miles in length, becomes a necessity on the part of the Government and of the owners of the channel, if it is desired to render our naval armament doubly effective, and to maintain and stimulate our commercial development.

But in every engineering enterprise it is important "to sit down first and count the cost," as well as the revenue.

This has been done on the part of the Government and as already stated it was estimated at over $7,000,000, but of this amount $3,249,663.56 was for dredging in the approaches, and $4,355,807.80 was for the canal, 100 feet wide, and its locks, bridges and other works, including land damages. These dimensions are, however, unnecessarily wide for the present, especially in view of the short length

of the deep cut. There is no need of a double track through these four miles and hence a smaller section would prove just as effective and much cheaper. The Suez Canal is but seventy-two feet wide at bottom, and the Amsterdam eighty-six, while the Sault, which to-day outranks in tonnage any canal in the world, was only 64 feet wide and 13 feet deep up to the date of its enlargement, which was completed in 1882. The present dimensions are 108 feet wide at the narrowest part, increasing to 500 just above the lock, and 16 feet deep, the section being rectangular.

In 1840, only fifty-two years ago, when the Senator from Michigan proposed to have the Government build the "Soo" Canal, Henry Clay opposed it because, as he said, it was "*A work beyond the remotest settlement in the United States, if not in the moon.*"

On August 26, 1852, the Government granted 750,000 acres of public lands to the State of Michigan as a subsidy for this canal, which was constructed by a private company and turned over to the State in 1856. In 1869, the State provided for the future transfer of this property to the Government, and it has proven to be one of the best investments the country has ever made.

But to return to the question of width. As intimated, by a reduction of width to a limit sufficient to pass the largest ocean-going vessels in single file, the cost of construction may be kept within $3,000,000 for the fourteen-mile canal, while the revenue would be derived from the entire foreign commerce of Baltimore going to Northern and Eastern ports, which is ninety per cent. of the total, and a large local and coastwise tonnage, all of which aggregate for the two bays, 27,000,000 tons. Of this amount twenty per cent. would no doubt traverse the canal. This at the low rate of fifteen cents per ton would produce a revenue of $810,000. After deducting expenses it should leave not less than fifteen per cent. for dividends and interest on the capital.

As the economic value of a waterway is dependent upon the ratio of its length (and hence its cost) to the distance saved, it will be seen by comparison that there are only two

canals in the world which surpass this one in this particular—they are the Suez and the proposed Nicaragua. The Suez canal, 100 miles long, saves 3,750 miles. Its length is therefore nearly three per cent. of the distance saved. The Nicaragua, 169 miles long, is less than two per cent. of the 10,000 miles which it would save.

The Chesapeake and Delaware is but four per cent. of its greatest saving.

The North Sea and Baltic, sixty-one miles long, is twenty-seven per cent. of distance saved.

The length of the Florida Ship Canal would equal twenty-nine per cent. of the distance cut off, but as it would be 169 miles long and transit through it would be slow, the economy in time would be only twelve hours between New York and New Orleans.

The length of the Amsterdam Canal is forty-two per cent. of the former route.

In short, it would seem that there are but few, if any, places on the face of the globe where so small an expenditure of capital gives promise of such large and immediate returns, where there is so large a commerce in sight in the adjacent and tributary waters, where the benefits to the overland lines of transportation will be so great and where the work will be of the utmost practical utility to the Government in increasing the efficiency of its naval force in time of war, and a potent factor in removing cause for war with any foreign power in times of peace.

In fact its construction becomes a matter of necessity if we hope to keep pace with and aid in the symmetrical development of the commercial interests of our country as a whole.

The lecture was closed with a number of views taken along the line of the Chesapeake and Delaware Canal, illustrating the capacity of the waterway for enlargement and the most improved form of machinery available for construction.

STUDIES ON THE STRATIFICATION OF THE NORTHERN ANTHRACITE FIELD OF PENNSYLVANIA.

By Henry A. Wasmuth, M. E.

The Susquehanna River at one time crossed the nearly horizontal anthracite measures, until the whole strata precipitated, either by the shrinkage of the earth's crust, or by volcanic influences, or by both, resulting in the origin of the present long and narrow synclinal of the northern anthracite field. This theory is proven beyond doubt by the washout of the Baltimore coal seam of Forty Fort Colliery, demonstrated in *Figs. 1* and *2* of accompanying plate.

Simultaneously with the precipitation of the strata, the basin, curbed by conglomerate, became filled with water, sand, pebbles and sulphuric clay by the river until leveled up, the water found an outlet towards north near Nanticoke, most probably by the Harvey's Creek bed, then running towards Shickshinny Creek and finally about Mocanaqua across the anthracite measures towards the south.

Since that time, most probably at the beginning of the cretaceous period, erosion went on steadily, the Susquehanna River eroded deeper and deeper the curb of conglomerate at its inlet and outlet, deposited and re-deposited the debris thus produced or carried on, until the present condition of the Wyoming Valley was brought about.

The greater part of the carboniferous formation, with its synclinals and anticlinals of England, Belgium and Westphalia is overlaid by enormous layers of the cretaceous formation.

The lignite deposits of the cretaceous period of Central Russia (Ryasan government) and of Bohemia have a roof of sulphuric clay from a few feet to 400 feet thick, partially overlaid by quicksand in Russia and by gravel from the mountain streams in Bohemia. The sulphuric clay of the buried valley near Forty Fort Colliery is similar to the clay

of the lignite deposits referred to, and therefore the conclusion is justified that the clay of the buried Wyoming Valley is of the cretaceous period, and that the disturbances of the horizontal anthracite measures are assignable to the cretaceous period.

Assuming that at Forty Fort Colliery the distance from outcrop to outcrop of the Buck Mountain coal seam is 27,000 feet, and the depth of its synclinal 900 feet, then the breadth of the horizontal coal seam of the present synclinal would be about 27,100 feet, or in other words, at the time of the precipitation of the strata, its horizontal breadth of 27,100 feet had to be accommodated within a horizontal distance of 27,000 feet, which by its hard and solid condition could take place only by fractures and dislocations of the strata.

This theory is verified by the fact, that a breadth of the horizontal strata of far more than the distance from outcrop to outcrop of the anthracite measures has been accommodated within the basin by numerous longitudinal faults or overlaps, all over the northern anthracite field, and the whole anthracite region.

An investigation of the workings of Forty Fort Colliery will convince one that the strata, near the foot of the underground slope on the eleven-foot seam, is dislocated by a longitudinal fault *B*, *Fig. 1*.

The vertical dislocation of the eleven-foot seam is about twelve to fifteen feet and consequently the whole series of strata is dislocated similarly. The fault *B* undoubtedly also intersected and dislocated the ancient river bed about the slope as demonstrated in *Figs. 1* and *2*.

Most probably the fault *B* is identical with the longitudinal fault developed by the adit of Harry E. Colliery many years ago, yet to be investigated. Two more longitudinal faults have been developed in this colliery; one at the head of the inclined plane and the second one by the underground slope and workings. If fault *B* in Forty Fort Colliery is identical with the fault in the adit of Harry E. Colliery, then the two other faults referred to will have been developed also on the Baltimore seam in Forty Fort

Colliery by this time. Since my observations, four years ago, I have no knowledge of the developments.

Each of the faults in Harry E. Colliery referred to will show similar appearances as demonstrated in *Figs. 1* and *2*, and the ancient river bed shifted southwards and higher by each of them in accordance with the vertical dislocation of the strata.

The maps of the Second Geological Survey of Pennsylvania exhibit numerous anticlinals between Pittston and the western outcrop of the basin, but none of them is in existence; they are merely longitudinal faults, and therefore it is obvious that the elevation and horizontal position of the ancient river bottom about Nanticoke must be quite different from the elevation and position in Forty Fort Colliery. Of course, the fall of the ancient river between those points might have been slight, moderate, or considerable, and the relations of the faults to the ancient river bed will prove to be in accordance with the vertical dislocation of the strata, which could be demonstrated only by a longitudinal section of the ancient river bottom. Nevertheless, each of the longitudinal faults, marked as anticlinals on the maps of the Second Geological Survey of Pennsylvania, will require especial consideration in order to avoid costly incidents in mining.

Undoubtedly, the sand and gravel of the ancient river bed at its inlet and outlet are still in connection with the Susqehanna River and also with those creeks which intersect the curb or northern outcrop of the carboniferous formation, hence the gravel layer must be filled with water constantly, and tapping the gravel by mine workings necessarily must cause flooding of the mine to a greater or less extent.

The danger of the ancient river bed is pretty well appreciated, and to avoid flooding of the mines and great loss of property considerable pillars of coal have been left unmined and are wasted forever.

Assuming that on the eleven-foot seam the coal pillars of at least 150 yards on the dip and of the Baltimore seam on each bank of the ancient river forty yards of coal are

left unmined, both seams yielding twelve feet of coal, the loss of tonnage per mile along the ancient river bed would be about:

	Cubic Yards.
Eleven-foot seam, 120 pillars, 150 × 6 × 2, ...	= 216,000
Baltimore seam, 1,760 × 80 × 2, ...	= 281,600
	497,600

equal to about 400,000 tons of marketable coal.

These coals could be mined very advantageously, for no additional investment would be required.

In order to lessen the waste to the Commonwealth and at the same time to lessen the danger constantly impending over those mines operating in the neighborhood of the ancient river, I offer the following suggestions:

Perhaps six, eight or ten pillars of the eleven-foot seam, below the ancient river bottom in Forty Fort Colliery, or in another suitable locality, ought to be robbed properly in order to secure a perfect break of the ancient river bottom. The great weight of the overlying clay certainly would produce a precipitation of the strata of from two to four feet, the gravel of the ancient river bottom would become mixed with clay and its connection with the Susquehanna River "shut up" almost completely. *Fig. 3.*

The next robbing of pillars and breaking down of the ancient river bottom would accomplish a complete "shut up" of the water from the Susquehanna River.

A break of the ancient river bottom about the town of Luzerne would have similar effects against the water from the higher ancient river bottom and from the mountain creek eventually; the water of moderate quantity of the gravel of the ancient river bottom would remain stagnant and all the coal between those breaks and on the right bank of the Susquehanna River, excepting the justified loss in mining, could be mined with safety.

The four to six feet thick lignite bed of Russia, mentioned already, is overlaid by a clay roof of variable thickness with local pockets of quicksand of from thirty to eighty feet thick, but not a gallon of water from the quicksand or from atmospheric precipitations has entered the mines by

the breaks and precipitations of the surface caused by robbing of the coal bed.

The lignite bed of Bohemia, referred to, is from thirty to fifty feet thick, with a roof of clay from a few feet to 400 feet thick, which mostly is overlaid by heavy water carrying gravel from the mountain streams. Many acres of surface have precipitated from ten to fifteen feet by the incomplete robbing of the big coal deposit, but during eight years I never learned that surface water, or even water from the mountain streams had entered the mines by those breaks or funnels of the surface.

The outlay to carry out the above suggestions would be redeemed many times, and there is no doubt at all that cooperation of the land owners and coal operators would be rewarded by a great success of the mining industry.

PHILADELPHIA, September, 1892.

HOW THE EARTH IS MEASURED.*

BY PROF. J. HOWARD GORE.

[*A lecture delivered before the Franklin Institute, November 30, 1891.*]

The lecturer was introduced by Professor Frazer, and spoke as follows:

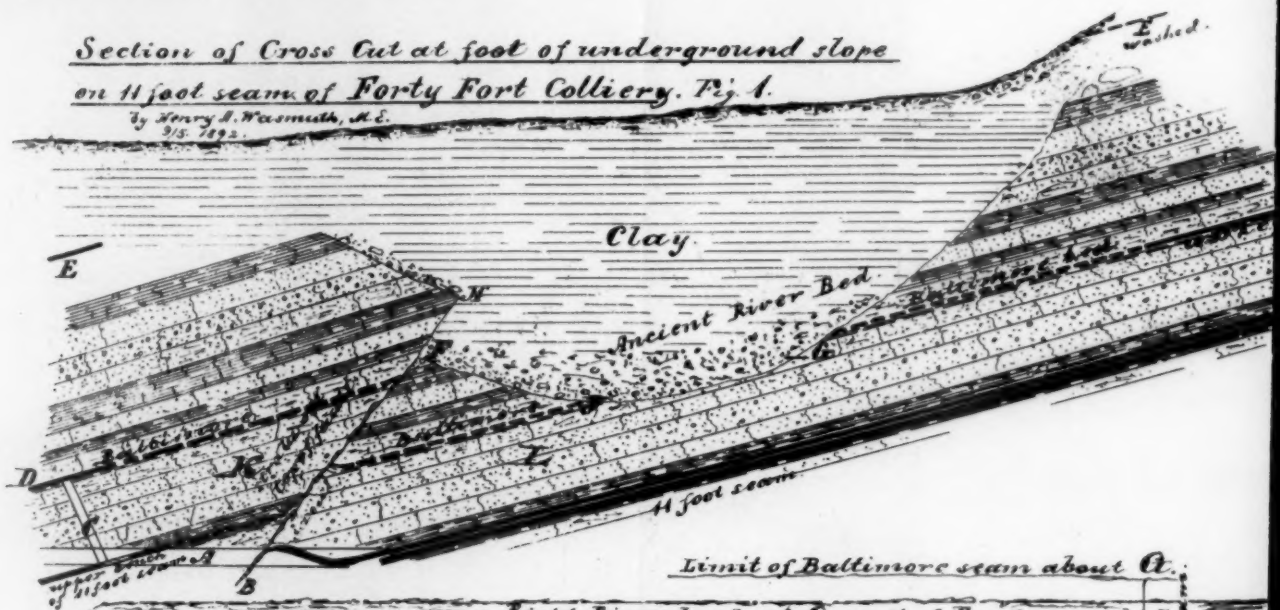
From the time the infant brain throbs with sentient energy while reaching with its questioning eye or grasping hand after the unknown until the feeble mind no longer directs the dimmed vision or commands the palsied arm there is a longing to know the nature of all that surrounds us.

The air we breathe, the water that slakes our thirst, the sky that hems us in have been the subjects of many anxious thoughts: the stars that stud the heavens, the moon with its changing phases and the sun in his daily course have

* Certain portions of this paper are taken from the author's work on *Geodesy* published by Houghton, Mifflin & Co.

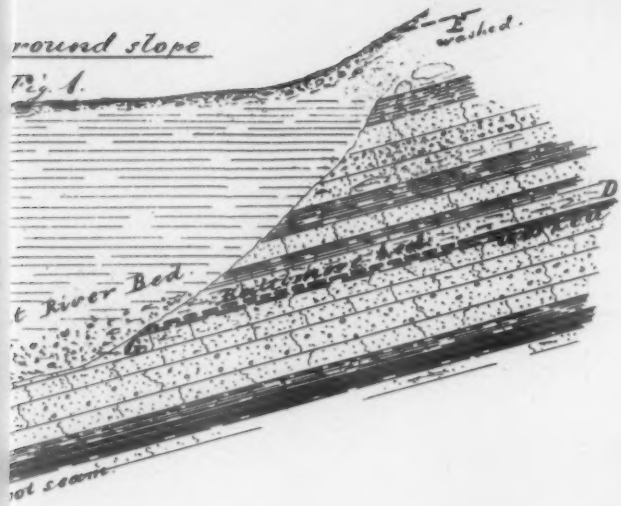
Section of Cross Cut at foot of underground slope on 11 foot seam of Forty Fort Colliery. Fig. 1.

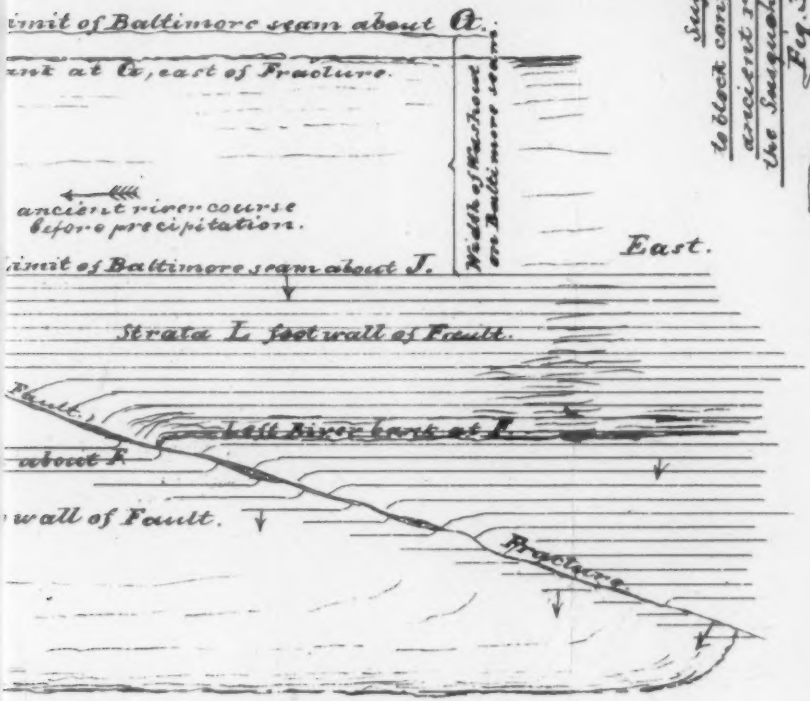
by Henry A. Wasmuth, A.E. 9/5. 1892.



Horizontal Section at F. Fig. 2.

(Wasmuth.)




imit of Baltimore seam about A.
nt at A, east of Fracture.
Width of Workable Coal on Baltimore seam.
ancient river course before precipitation.
East.
imit of Baltimore seam about J.
Strata L foot wall of Fault.
Fault.
left River bank at F.
about F.
wall of Fault.
Fracture.

ection at F. Fig. 2.

Kork
11 foot seam robbed

taken their places before the symbol of interrogation. And in the enlarging catalogue of queries there is ever present: What is the earth? What is its size? What is its shape?

The speculative Greek, with his all-sufficient Pantheon, placed it on Atlas' shoulder and was content or rolled it amongst crystalline balls to the music of the spheres. The contemplative Hindoo found it a fit subject for theories, and so have every peoples until Copernicus fossilized theory into fact by making the earth globular revolving in an orbit, and Newton holding it in place by the principle of universal gravitation.

To a person on a great eminence the earth appears as a vast plain, with the horizon supporting the sky as a dome-shaped roof. This appearance has been noticed by peoples at all times, and has called into existence flat-earth theories without number. A spirit of patriotism has prompted all to make one's own country occupy the most prominent geographical position and assume the maximum importance. Complimentary and laudatory myths have been invented by each tribe to account for the formation of its own country, while averring that all other tribes occupy insignificant areas formed of the useless fragments their builders graciously donated. Nor has this spirit been restricted to unlettered tribes; it showed itself long after the art of map-making was known, rendering it possible to determine from what country a map emanated by the relative sizes of the countries thereon. Likewise, as one looks out from a suitable position, one sees the horizon like a circle whose centre is the observer, and the sky above apparently a globe with the same centre. Thus it is that the Hindoos at the equator and the Scandinavians near the pole apply each a name to their own country which signifies the "central habitation."

The "hub" theory is not restricted to one country alone. The Greeks made Olympus the centre, the Egyptians Thebes, the Assyrians Babylon, the Hebrews Jerusalem; while the Chinese have regarded their land as the central empire since the time they sent astronomers to the four points of the compass to locate the equinoxes and the solstitial points.

One of the most primitive ideas regarding the earth represented it as an immense plain, or flat island, surrounded on all sides by an interminable ocean. This ocean in the minds of the Greeks was only a river, called Okeanos, and into this the sun made each night a plunge, to arise in the morning on the opposite side of the earth. At the extremities and borders were placed the "fortunate isles," or imaginary regions inhabited by giants, pigmies, and such mythical creatures as a vivid imagination could call into being. But when men began to have experience of the sea by navigation, the horizon always observed as circular led to the notion that the ocean was bounded, and the whole earth came to be represented as a circle, beneath which were roots reaching downward without end.

The cooling of the sun from his daily bath demanded some change in the material into which he plunged. And as he could not go down on one side and come up on the other without making the subterranean journey, some provision had to be made for his passage. It was easy to imagine a tunnel through which he could pass, but as soon as the progressive and retrograde movements in his places of setting and rising were recognized, it was necessary that the support of the earth be honeycombed with passages. The Buddhist priests declared that the sun passed between the pillars which supported the earth. And no sooner did they find this theory acceptable than they applied it to their ends. For, said they, these columns are sustained by virtue of the sacrifices which were made to the gods, and any indifference on the part of the worshippers might cause a collapse of the earth.

The ancient Greenlanders affirmed that the earth is upheld by pillars which are so consumed by time that they crack, thus quaking the earth; and were it not for the incantations of the magicians, the earth would long since have broken down. Thus we see a myth reaching

> "From Greenland's icy mountains
> To India's coral strand."

The Hindoos held the earth to be hemispherical, and to

be like a boat turned upside down upon the heads of four elephants, which stood on the back of an immense tortoise. This support, like a superficial answer, was sufficient until some curious questioner insisted upon knowing upon what the tortoise rested. The answer, upon the universal ocean, was soon proffered and gladly accepted, until the application of the further test, on what does the ocean stand? The ultimatum was then reached; the theory so boldly advanced and so ingeniously sustained needed a foundation principle; this it received in a shape that stilled further doubts and strengthened the whole superstructure: What supports the ocean? Why, it goes all the way to the bottom. This form of reply did not disappear with those who first made it, nor has it found a place in earth theories alone. Almost every science has advanced its line of interrogation points until a final all-sufficient answer is given, or an accepted axiom quoted.

Anaximander, a philosopher of the sixth century before Christ, represented the earth as a cylinder, the upper face only being inhabited. By some process now not known he computed its proportions, and gave as the result that its height was one-third of its diameter, and that it floated freely in the centre of the celestial vault. The doctrine of "sufficient reason" prevailed then, or was invented to fit this particular case, because when asked why this cylinder did not tip over, he replied that in the absence of a reason why it should tip in any one direction rather than in another, it did not tip at all, hence remaining in this state of helpless indecision. A fellow-philosopher, recognizing the importance of air in the economy of nature, supported the cylindrical earth of Anaximander on compressed air, which, owing to the vague and apparently imponderable character of air, did not suggest the need of a resting place for this air cushion.

Aristotle relied more upon fancy than upon fact, and deduced conclusions from logic and the nature of things rather than from observation. He reasoned from what he deemed natural to what must be or is. In answer to the question, Is the earth at rest? he replied, "The earth is

in repose, because we see it to be so, and because it is necessary that it should be, since repose is natural to the earth." He also affirmed that a circle is a perfect line, being uninterrupted and without ends; and, therefore, the stars, created by God to endure forever, must have an eternal motion, and being perfect creations they must move in the perfect line—the circle. The heavens, also, possessing this divine attribute of perpetuity, must move in a circle. Then, as a grand climax, he asserted that since in every revolving circle there is a point of absolute repose, the centre, the earth, being at rest, must occupy this central point.

Strabo, the geographer, who made the first century of the present era illustrious by his maps, declared the earth to be spherical, for in all his investigations and study regarding the travels of sailors and explorers he found no mention of the end of the earth. To him it appeared central and motionless, and in his consistent ignorance he unyieldingly affirmed that the entire habitable globe was represented on his maps, and was in shape like a cloak 8,000 miles long and 3,600 miles in width, the greater dimension being from east to west; hence our term longitude for degrees counted in that direction.

Bede, known as the Venerable, who lived in the eighth century, regarded the earth as formed upon the model of an egg. Being an element, it is placed in the middle of the universe as the yolk is in the middle of the egg; around it is the water, like the white surrounding the yolk; outside that is the air, like the membrane of the egg; and around all is the fire, which closes it in as does the shell. The earth, being thus in the centre, receives every weight upon itself; and though by its nature it is cold and dry in its different parts, it acquires, accidentally, different qualities; for the portion which is exposed to the torrid action of the air is burned by the sun, and is uninhabitable; its two extremities are too cold to be occupied, but the portion that lies in the temperate region is habitable. The ocean, which surrounds it by its waves as far as the horizon, divides it into two parts, the upper of which is inhabited by us, while

the lower is inhabited by our antipodes; although not one of them can come to us, nor one of us go to them.

As in other theories, a support was needed. To meet this requirement Edrisi, an Arabian geographer, broached the idea that the egg-like earth floats in the great ocean as in a basin.

Although we are told that Pythagoras and Thales taught that the earth was spherical, we see that their teaching was without avail on this point for nine centuries, while the shape of the earth was the play of many foolish fancies. Bede again rounded it off and gave to it the egg shape which it retained in the minds of men for 1,000 years. Many of these theories were so erroneous that they were in nowise links in a great chain which could bind all peoples into unanimity of belief. But while many were beating time without marching, others were making progress along hopeful lines.

Now that the development of ideas had carried men far enough to accept a spherical globe, it was only natural that speculations were rife as to its size, and it was equally natural that some one should come forward with a method for determining this magnitude; and while this method might in itself be inaccurate or unsatisfactory, yet it would serve as a quickening force in the elaboration of better and still better plans.

Before attempting to measure the entire earth it was necessary that considerable success should have been met with in measuring limited portions of its surface. Just when this art was first practised is hard to ascertain; probably when Joshua was sent to spy out the land, he had in view quantity as well as quality.

We are told by Herodotus that the credit of discovering geometry belongs to the Egyptians, who found need of its principles in the restoration of those boundaries of fields which were obliterated by the overflow of the Nile. He also gives us the method of procedure when the river god consumed portions of a man's landed possessions. "If the river carried away any portion of a man's lot, he appeared before the king and related what had happened, upon which

the king sent persons to examine and determine by measurement the exact extent of the loss; and thenceforth only such rent was demanded of him as was proportionate to the reduced size of his land. From this practice, I think, geometry first became known in Egypt, whence it passed into Greece."

With the acceptance of the belief that the earth was spherical came the notion that by finding the length of 1° on the earth's surface a simple multiplication by 360 would give the entire circumference, and this circumference being the same for the same sphere the measurement of 1° would suffice for the determination of the size of the earth.

Following out this idea, Eratosthenes communicated in 276 B.C. a value for the earth's circumference, followed in 135 B.C. by Posidonius, as results of approximate measures and erroneous observations.

Just here we must take a long step chronologically but not geographically. The exact sciences ceased to be cultivated in Greece and Egypt. They slumbered for centuries and awakened in Arabia. When the Arabians adopted the Mohammedan religion they became ambitious for mastery not alone in the field of battle, but in the arts and sciences. They embraced, extended and utilized the knowledge they found during their occupation of Egypt. They preserved trigonometry from oblivion and handed it down to us in its present shape, while to them we are indebted for the beginning and early development of practical astronomy. The Arabians reached their zenith under Caliph Almamon. He was not only a scholar, but a patron of the sciences, and assembled about him the most learned men of that period, among whom were Acaresimi, Alfraganus and Albategni.

This wise caliph was the next to make a contribution to the world's knowledge of the size of the earth. In 819 he imposed upon his astronomers the task of measuring a meridional arc on the plain of Singar by the Arabian Sea. They divided themselves into two parties, and starting from a given point, one party went north, measuring with wooden rods as they went, the other due south, likewise

measuring as they went. Each party continued, the former until they reached a point where the altitude of the pole was just 1° higher than it was at the starting point, while the other did not stop until they found a place where the altitude had decreased by 1°. Thus we see both groups had gone just a degree. The northward party had measured fifty-six miles, the southward, fifty-six and two-thirds miles.

It is said that they repeated their measurements and obtained identically the same results. However, others affirm that, appreciating the impracticability of the successful discharge of their duties, they adopted the value given by Ptolemy, which is perhaps about the mean of the two just given.

The method here described possessed geodetic features far in advance of those employed by the Greek mathematicians, but we have no information regarding the way in which the altitude of the pole was determined. From a lack of exact data as to the length of their unit, we are unable to form any opinion as to the accuracy of their result.

For 700 years speculation slumbered, and investigation was ignored. A cloud of ignorance hung over the world like a pall, and the attainments of the earlier inhabitants did not even remain as a shadowy dream. The discovery of mathematical writings left in Spanish cloisters by their Moorish invaders awakened some interest in the study of the exact sciences, and from the oblivion of the dark ages arose, Phœnix-like, the genius of that grander culture then begun, now unfinished.

In the opinions of men the earth was a plane, and again there was that painful, tedious uplifting of the benighted people to the realms of truth. Fortunately, the demonstrations were not left to the theorist alone; the science of navigation had by this time enabled men to venture beyond their littoral thoroughfares, and Magellan, circumnavigating the world in his three-years' voyage, placed beyond the confines of hypothesis the globular form of the earth.

In the ignorance of methods of determining differences

of longitude, it was impossible to ascertain the amplitude of an arc extending east and west. The determination of latitudes was an early art, but the measuring of an arc of meridian whose amplitude was, centuries ago, approximately ascertainable was limited to direct measurement.

Inasmuch as the task of finding a suitable stretch of country fulfilling the required conditions was difficult, the number of direct determinations were few, being restricted to Fernel, 1525, and Norwood, 1633.

[*To be continued.*]

MAXIMUM STRESSES FROM MOVING SINGLE LOADS IN THE MEMBERS OF THREE-HINGED ARCHES.

By Emrick A. Werner.

[*Continued from p. 311.*]

EXAMPLES.

Before beginning with the calculation of the stresses, it must be shown how are caculated the reactions and moments of the external forces and how the loadings can be reduced to concentrated panel loads.

Moment Table.—

Calculation of Moment Table.—

$$R_m = a\,W + b\,(W + W') + c\,(W + W' + W'') + \ldots.$$

$$R'_m = a\,W' + (a + b)\,W'' + (a + b + c)\,W''' + \ldots$$

$a, b, c \ldots$ distances between the loads $W', W'', W''' \ldots$

Check. $R_m + R'_{m'} = W_{(m+m')}$ = total load on $(m + m')$ multiplied by that distance.

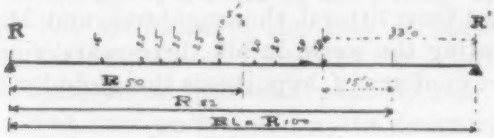
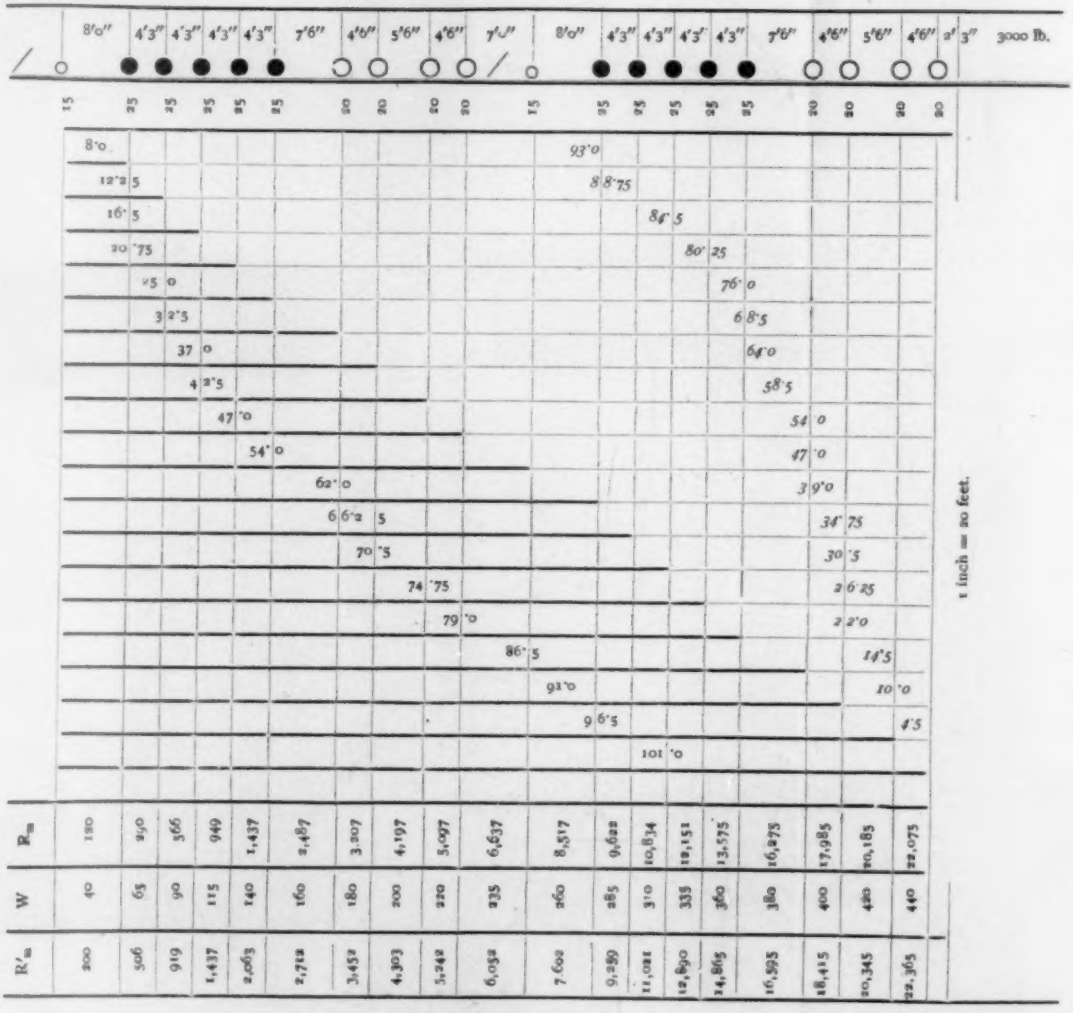


Fig. 2.



R_n	180	250	366	949	1,437	2,487	3,207	4,197	5,097	6,637	8,517	9,622	10,834	12,151	13,575	16,875	17,985	20,185	22,075
W	40	65	90	115	140	160	180	200	220	235	260	285	310	335	360	380	400	420	440
R'_n	200	506	919	1,437	2,063	2,712	3,452	4,303	5,242	6,052	7,602	9,259	11,021	12,890	14,865	16,595	18,415	20,345	22,365

FIG. 1.

Application for Different Positions of the Loads.—

$$R_{50} = 5 \times 140 + R_{25} = 700 + 1{,}437 = 2{,}137$$

$$R_{100} = R\,l = 33 \times 220 + R_{47} = 7{,}260 + 5{,}097 = \quad 12{,}357$$

$$R'_{100} = R'\,l = 20 \times 220 + R'_{47} = 4{,}400 + 5{,}243 = \quad 9{,}643$$

$$R\,l + R'\,l = W\,l = 220 \times 100 = \quad 22{,}000$$

The same check can be applied to R_{50}, in making $l = 50$.

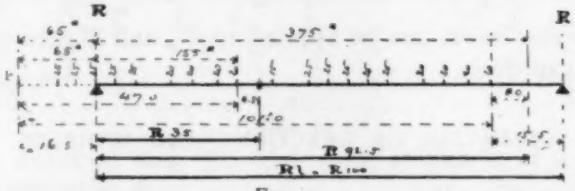


FIG. 3.

$$R_{35} = 4{\cdot}5 \times 155 + \left[R_{47} - [R_{16{\cdot}5} + 65 \times (47 - 16{\cdot}5)]\right] = 3{,}247$$

Note.—155 = load *on the span* before x including load on x $65 \times (47 - - 16{\cdot}5) = W_m$ m counted from R_{47}.

$$R_{92{\cdot}5} = 8 \times 375 + \left[R_{101} - [R_{16{\cdot}5} + 65 \times (101 - 16{\cdot}5)]\right] = 19{,}017$$

$$R_m = Rl = 15{\cdot}5 \times 375 + \left[R_{101} - [R_{16{\cdot}5} + (101 - - 16{\cdot}5) \times 65]\right] = 21{,}829$$

$$R'\,100 = R'l = R'_{101} - R'_{12{\cdot}25} - 16{\cdot}5 \times (440 - 65) \quad = 15{,}671$$

Check $Rl + R'l = Wl = 375 \times 100 = 37{,}500$

The same check can be applied to R_{35} and $R_{92{\cdot}5}$ in making $l = 35$ resp. $92{\cdot}5$.

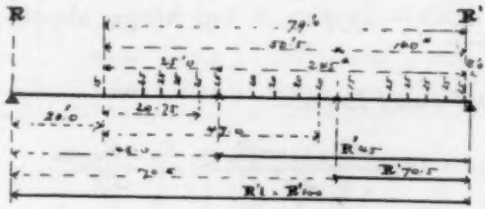



FIG. 4.

$$R'_{45} = R'_{79} - R'_{20\cdot75} - 25 \times (360 - 115) = \quad 7{,}303$$

Note.—$R'_{20\cdot75}$ never includes the load on x.

$$R'_{70\cdot5} = R'_{79} - R'_{47} - 50\cdot5 \times (360 - 220) = \quad 2{,}552$$

$$R'_{100} = R'l = 20 \times 360 + R'_{79} = 22{,}065$$

$$R100 = Rl = 1 \times 360 + R79 = 13{,}935$$

Check $Rl + R'l = Wl = 360 \times 100 = 36{,}000$

The same check can be applied to R'_{45} and $R'_{70\cdot5}$ in making $l = 45$ resp. $70\cdot5$.

CALCULATION OF REACTIONS AND MOMENTS.

Vertical reactions R

$$R = Rl \div l$$

Horizontal reaction

$$Hf = R\ l \,.\, \frac{1}{2} - W_1 \left(\frac{l}{2} - g_1\right) - W_2 \left(\frac{l}{2} - g_2\right) =$$

$$= R'l \,.\, \frac{1}{2} - W_3 \left(\frac{l}{2} - g_3\right) = \frac{R'\,l}{2} - R_t$$

Moments.—

$$M_x = R\,x - W_1\ (x - g_1) - Hy = Rl \,.\, \frac{x}{l} - R_x - Hf \,.\, \frac{y}{f}$$

$$= R'\,(l - x) - W_2\,(g_2 - x) - W_3\,(l - x - g_3) - Hy$$

$$= R'l \,.\, \frac{x}{l - x} - R'_x - \left(\frac{R'\,l}{2} - R'_t\right)\frac{y}{f}$$

f = rise of arch = height of top hinge above abutment hinges.

Concentrated Panel Loads.—

$$p = \frac{R_{x+\Delta x} - R_x}{\Delta x'} - \frac{R_x - R_{x-\Delta x}}{\Delta x}$$

Δx, $\Delta x'$ = length of panels.

LOADS AT REST.

I.

Upright Arch with Circular Line of Thrust.

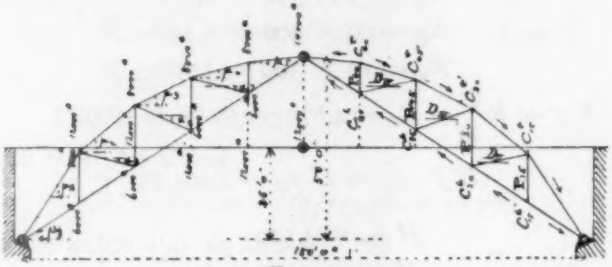


FIG. 5.

One hundred and fifty feet span, 10 panels 15 feet each, 50 feet rise of arch.

The thrust is taken up fully by the upper chord which has thus the form of the circular line of thrust.

The arch shall have *only diagonals in tension.*

The dead load is taken as load at rest.

It is assumed to 26,000 pounds per panel point.

Of the dead load 92,000 pounds are acting on the roadway, 8,000 pounds on the top chord, and 6,000 pounds on the bottom chord. The roadway is twenty-five feet above the abutment hinges.

h = depth of truss.

h	x	y	f	$\frac{y}{f}$	μ		α		
					tan.	*cos.*	*tan.*	*cos.*	
13·54	15	23·54		0·4708	1·5693	0·537	—	—	$tan.\ f = \frac{50}{75} = \frac{2}{3}$
16·40	30	36·40		0·7280	0·8573	0·759	0·2360	0·973	$cos.\ f = 0·832$
14·26	45	44·26	50·0	0·8852	0·5240	·885	0·4266	0·919	
8·60	60	48·60		0·9720	0·2893	0·960	0·2840	0·961	
0·0	75	50·00		1·0000	0·0933	0·995	—	—	

FIG. 6.

$$R\,l = R'\,l = 17{,}550$$
$$R_{15} = 0$$
$$R_{30} = 390$$
$$R_{45} = 3 \times 390 = 1{,}170$$
$$R_{60} = 6 \times 390 = 2{,}340$$
$$R_{75} = 10 \times 390 = 3{,}900$$
$$H\,f = R\,\frac{l}{2} - R_{75} = 4{,}875 \div 50 = H = 97{\cdot}5$$
$$H\,f\,.\,\frac{y}{f} = H\,y_{15} = 2{,}295{\cdot}15$$
$$H\,y_{30} = 3{,}549$$
$$H\,y_{45} = 4315{\cdot}35$$
$$H\,y_{60} = 4738{\cdot}5$$

Horizontal Chord Stresses.—

Bottom Chord:

$$C_x = \left(\frac{M}{h}\right)_x$$

H being taken up fully by the top chord.

$$\left(\frac{M}{h}\right)_x = R\,l\,.\,\frac{x}{l} - R_x - H\,y = R'\,l\,\frac{x}{l-x} - R'_x - H\,y$$

$$C_{15} = \frac{1}{13{\cdot}54}(1{,}755 - 0 - 2{,}295) = -\,39{,}900$$
$$C_{30} = -\,26{,}200$$
$$C_{45} = -\,15{,}300$$
$$C_{60} = -\,6{,}800$$

Top Chord:

$$C_x = \left(\frac{M}{h}\right)_x - H$$

$\left(\frac{M}{h}\right)_x$ being negative produces tension in the top chord, hence:

$$C_{15} = -\,97{,}500 + 39{,}900 = -\,57{,}600$$
$$C_{30} = -\,71{,}300$$
$$C_{45} = -\,82{,}000$$
$$C_{60} = -\,90{,}700$$
$$C_{75} = -\,97{,}500$$

Horizontal Stress in the Diagonals.—

$$D_x = C_x - C_{x-\Delta x} = \left(\frac{M}{h}\right)_x - \left(\frac{M}{h}\right)_{x-\Delta x}$$

From Bottom Chord:

$$D_2 = -\ 26{,}200 + 39{,}900 = +\ 13{,}700$$

$$D_3 = +\ 10{,}700$$

$$D_4 = +\ 8{,}700$$

Check from Top Chord:

$$D_2 = 71{,}300 - 57{,}600 = +\ 13{,}700$$

and in the same way D_3 and D_4.

D being positive the diagonals run from the left to the right. From this direction of the diagonals follows the direction of the chord stresses, as shown in *Fig. 5*.

Vertical Stresses in the posts.

From Top Chord:

$P_{15} = C_{15} \tan \mu_1 - C_{30} \tan \mu_2 - D_2 \tan a_2 = 26{,}000$ pounds.

$P_{30} = C_{30} \tan \mu_2 - C_{45} \tan \mu_3 - D_3 \tan a_3 = 13{,}500$ pounds.

$P_{45} = C_{45} \tan \mu_3 - C_{60} \tan \mu_4 - D_4 \tan a_4 = 14{,}200$ pounds.

$P_{60} = C_{60} (\tan \mu_3 - \tan \mu_4) = 17{,}800$

From Bottom Chord (check):

$P_{15} = (C_{15} - C_{15}) \tan \mu_f - p = o - 26{,}000$ pounds $= 26{,}000$ pounds.

$P_{30} = (C_{30} - C_{15}) \tan \mu_f + D_2 \tan a_2 - p = 12{,}400 - 26{,}000 = = 13{,}600$

$P_{45} = (C_{45} - C_{30}) \tan \mu_f + D_3 \tan a_3 - p = 11{,}700 - 26{,}000 = = 14{,}300$

$P_{60} = (C_{60} - C_{45}) \tan \mu_f + D_4 \tan a_4 - p = 8{,}300 - 26{,}000 = = 17{,}700$

As the direction of the stresses in the chords cannot be foretold, but is found from the direction of the diagonals, which depends upon the sign of D, it is not possible to give the stresses in the chord members before D is calculated.

With these data, we find now the stresses in the members.

Bottom chord:

$$\frac{C}{\cos \mu_t} = \frac{C}{0{\cdot}832}$$

the members are under compression, C being negative.

First panel = second panel = 39,900 ÷ 0·832 = 48,000

Third panel = 31,900 pounds. Fourth panel = 18,700

Fifth panel = 8,200 pounds.

Top chord:

$$\frac{C_x}{\cos \mu_x} = \textit{compression.}$$

First panel = 57,600 ÷ 0·537 = 107,300

Second panel = 94,000

Third panel = 92,700

Fourth panel = 94,500

Fifth panel = 91,200 pounds.

Diagonals:

$$\frac{D_x}{\cos a_1} = \textit{Tension} -$$

Second panel = 13,700 ÷ 0·236 = 58,100

Third panel = 25,200

Fourth panel = 30,700

Posts:

P_{15} = 26,000 — 20,000 = 6,000 tension.

P_{30} = upper part = 13,500 — 8,000 = 5,500 tension.

lower part = 6,000 — 12,400 = 6,400 compression.

P_{45} = 14,200 — 8,000 = 6,200 pounds.

P_{60} = 17,800 — 8,000 = 9,800 pounds.

Computing these stresses we have the following strain sheet for dead load.

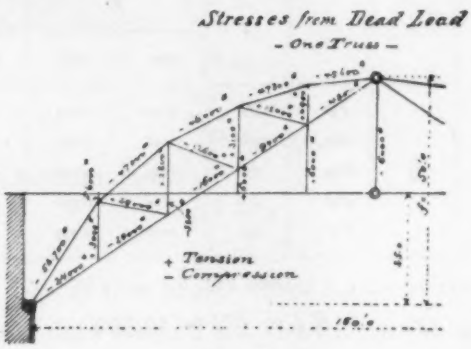


FIG. 7.

II.

Upright Arch with Parabolic Line of Thrust.

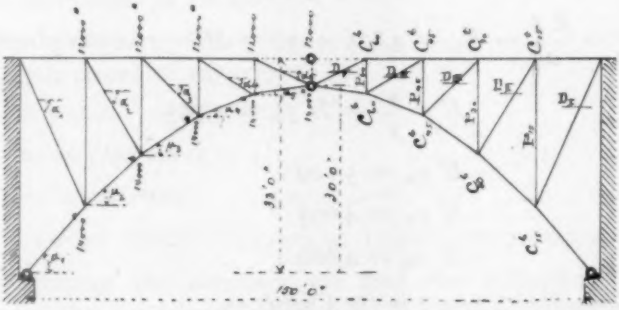


FIG. 8.

One hundred and fifty feet span, 10 panels 15 feet each, 30 feet rise of arch.

The thrust is taken up fully by the bottom chord. The arch shall have only diagonals in tension.

The dead is the load at rest. It is assumed to 26,000 pounds per panel point. Of this load 12,000 pounds are acting at the top chord, 14,000 pounds at the bottom chord.

h = depth of truss.

x	y	f	$\frac{y}{f}$	h	μ		α	
					tan.	*cos.*	*tan.*	*cos.*
15	10·8		0·36	22·2	0·72	0.811	1·48	0·559
30	19·2		0·64	13·8	0·56	0·872	0·92	0·736
45	25·2	30	0·84	7·8	0·40	0·928	0·52	0·887
60	28·8		0·96	4·2	0·24	0·972	0·28	0·963
75	30·0		1·0	0·0	0·08	0·997	0·20	0·981

(See Fig. 6.)

$$R\,l = R'l = 17{,}550$$

$$R_{15} = 0$$

$$R_{30} = 390$$

$$R_{45} = 1{,}170$$

$$R_{60} = 2{,}340$$

$$R_{75} = 3{,}900$$

$$H f = \frac{R\,l}{2} - R_{75} = 4{,}875 \div 30 = H = 162{,}500 \text{ pounds.}$$

$$H f \frac{y}{f} = H y_{15} = 1{,}755$$

$$H y_{30} = 3{,}120$$

$$H y_{45} = 4{,}095$$

$$H y_{60} = 4{,}680$$

Horizontal Stresses in the Chords.—

Top Chord:

$$C_x = \left(\frac{M}{h}\right)_x$$

$$C_{15} = 1{,}755 - o - 1{,}755 = o = C_{30} = C_{45} = C_{60} = C_{75}$$

Bottom Chord:

$$C_x = \left(\frac{M}{h}\right)_x - H = -H.$$

$$C_{15} = C_{30} = C_{45} = C_{60} = C_{75} = H = 162{,}500 \text{ pounds.}$$

Horizontal Stresses in the Diagonals.—

$$D_x = C_x - C_{x-\Delta x} = o$$

Stresses in the Posts.—

$$D = o$$
$$C = o$$
$$P = 26{,}000$$

Check from bottom chord

$$D = o$$
$$C = H$$
$$P = H\,(tan\ \mu_{x+\Delta x} - tan\ \mu_x) = 26{,}000$$

With these data we find the stresses in the members:

Top Chord.—Stress in all members equal to zero.

Bottom Chord

$$= \frac{C}{cos\ \mu} = \frac{H}{cos\ \mu}$$

First panel = 162,500 ÷ 0,811 = 200,000
Second panel = 186,000
Third panel = 175,000
Fourth panel = 167,000
Fifth panel = 163,000

Stress in Diagonals = O

Stress in all Posts

$= P = 26{,}000 - 14{,}000 = 12{,}000$ compression.

Computing the stresses we find the following strain sheet for the dead load:

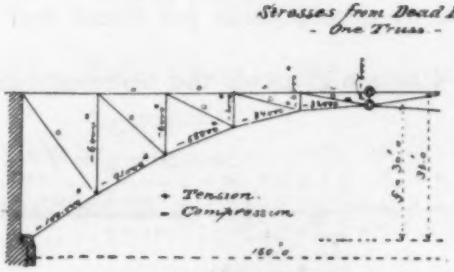


FIG. 9.

MOVING SINGLE LOADS.

I.

Upright Arch with Parabolic Line of Thrust.

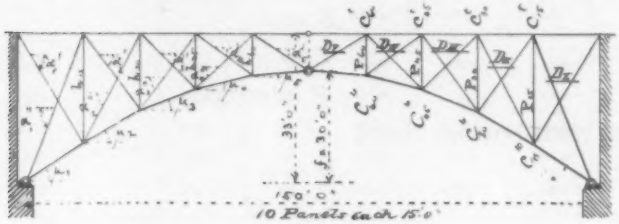


FIG. 10.

x	y	f	$\frac{y}{f}$	h	μ		a'		a''		
					tan.	*cos.*	*tan.*	*cos.*	*tan.*	*cos.*	
15	10·8		0·36	29·2	0·72	0·811	1·48	0·559	2·20	0·414	I
30	19·2		0·64	13·8	0·56	0·872	0·92	0·736	1·48	0·559	II
45	25·2	30·0	0·84	7·8	0·40	0·928	0·52	0·887	0·92	0·736	III
60	28·8		0·96	4·2	0·24	0·972	0·28	0·963	0·52	0·887	IV
75	30·0		1·00	—	0·08	0·997	0·20	0·981	—	—	V

The arch has 150 feet span, 10 panels 15 feet each, 30 feet rise. The arch shall have only diagonals in tension.

The thrust is taken up fully by the lower chord, which has the form of the line of thrust.

The dead load is assumed at 26,000 pounds per panel point. The stresses resulting from it are calculated under loads at rest.

The moving loads are the two engines of the moment table followed by 3,000 pounds per lineal foot of bridge. (See *Fig. 1.*)

The above diagram gives all the necessary data for the calculation.

FIG. 11.

Vertical Reactions.—The first driver over the left abutment makes W and Rl a maximum, and

$$R\,l = 49{,}306$$

$$R'\,l = 30{,}194$$

Hence

$$R = R\,l \div l = 328{,}700 \text{ pounds}$$

$$R\ minim. = 0$$

Horizontal Stress H of the Thrust.—

Maximum:

$$\frac{d\,H}{d\,g} = W - 2\,W_3$$

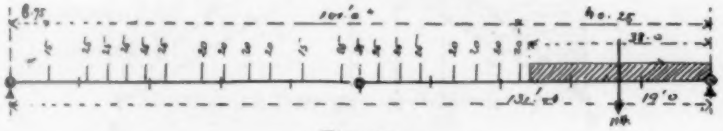


FIG. 12.

To the right of the dividing line (top hinge)

$$W = 554\ W_3\ 294$$

To the left of the dividing line

$$W = 554\ W_3\ 269$$

Whence

$$\frac{d\,H}{d\,g} = \begin{cases} 554 - 588 < 0 \\ 554 - 538 > 0 \end{cases}$$

and

$$R\,l = 41{,}951$$

$$R'\,l = 41{,}149$$

Check

$$R\,l + R'\,l = 83{,}100 = W\,l = 554 \times 150$$

$$R_{75} = 9{,}622$$

$$R'_{75} = 9{,}222$$

$$H\,f = R\,\frac{l}{2} - R_{75} = R'\,\frac{l}{2} - R'_{75} = 11{,}354$$

$$H = 11{,}354 \div 30 = 378{,}500 \text{ pounds}$$

Minim. $H = o$

Horizontal Stress C in the Chords.—

Top Chord: $C_x = \left(\frac{M}{h}\right)_x$

As no thrust is taken up by the top chord H is equal to zero, and we find

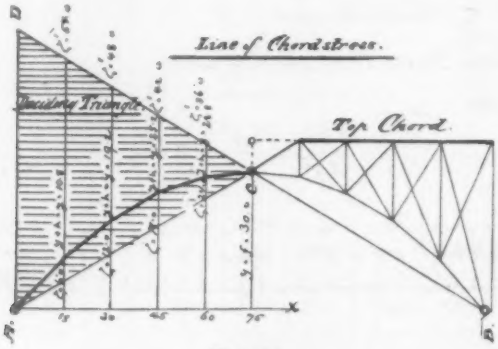


FIG. 13.

x	$\frac{\zeta' - y}{2f}$	$\frac{\zeta + y}{2f}$	$\frac{\zeta - y}{2f}$
15	+ 0·72	+ 0·28	— 0·08
30	+ 0·48	+ 0·52	— 0·02
45	+ 0·28	+ 0·72	— 0·12
60	+ 0·12	+ 0·88	— 0·08
75	0	0	0
	a	β	c

and have the general equation of the stresses in the top chord

$$\left(\frac{M}{h}\right)_x = a\, W_1 g_1 + C\, W_2 + C\, W_3 g_3$$

$$\left(\frac{M}{h}\right)_{15} = C_{15} = [0{\cdot}72\, W_1 g_1 + W_2 (15 - 0{\cdot}28\, g_2) -$$

$$- 0{\cdot}08\, W_3 g_3] \frac{1}{22{\cdot}2}$$

$$\left(\frac{M}{h}\right)_{30} = C_{30} = [0{\cdot}48\ W_1 g_1 + W_2 (30 - 0{\cdot}52\ g_2) - - 0{\cdot}12\ W_3 g_3] \frac{1}{13{\cdot}8}$$

$$\left(\frac{M}{h}\right)_{45} = C_{45} = [0{\cdot}28\ W_1 g_1 + W_2 (45 - 0{\cdot}72\ g_2) - - 0{\cdot}12\ W_3 g_3] \frac{1}{7{\cdot}8}$$

$$\left(\frac{M}{h}\right)_{60} = C_{60} = [0{\cdot}12\ W_1 g_1 + W_2 (60 - 0{\cdot}88\ g_2) - - 0{\cdot}08\ W_3 g_3] \frac{1}{4{\cdot}2}$$

Making $C = o$, we find g_m = *Maximum Line.*

Maxima.—

C_{15} *maximum.*

$$\text{Maximum line } g_m = \frac{1509}{28} = 53{\cdot}6$$

$$\text{Maximum span} = a + (g_m - a) = 53{\cdot}6$$

$$\left(\frac{d\,C}{d\,g}\right) max. = a\ W_1 - \beta\ W_2 = (a + \beta)\ W_1 - \beta\ W$$

$$= 25\ W_1 - 7\ W$$

W = total load on truss.

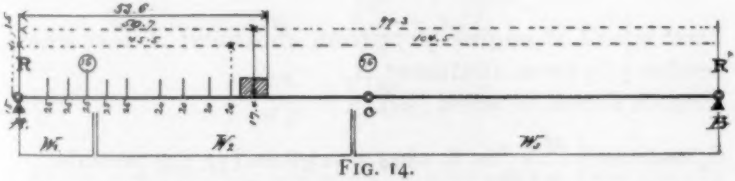


FIG. 14.

To the right of the dividing line $W = 222{\cdot}4\ W_1 = 75$

To the left of the dividing line $W = 222{\cdot}4\ W_1 = 50$

Whence

$$\left(\frac{d\,C}{d\,g}\right) = \begin{cases} 1{,}557 - 1{,}875 < o^* \\ 1{,}557 - 1{,}250 > o \end{cases}$$

* In the same way the corresponding positions of the loads for C_{30}, C_{45}, C_{60}, max. are formed from $\frac{dC}{dg}$.

and C_{15} maximum with

$R\,l = 27{,}542$ $R'\,l = 5{,}817$ check $R\,l + R'\,l = 222.4 \times 150 =$

$= 33{,}359$

$$R_{15} = 319 \quad R_{75} = 10{,}862 \quad H\,f = \frac{R\,l}{2} - R_{75} = 2{,}909$$

$$H\,y = H\,f.\ \frac{y}{f} = 2{,}909 \times 0{\cdot}36 = 1{,}047$$

$$R'_{15} = 2{,}800 \quad R'_{75} = o \quad H'\,f = \frac{R'\,l}{2} \quad R_{75} = 2{,}909$$

$$\left(\frac{M}{h}\right)_{15} = \left[R\ l\ .\ \frac{x}{l} - R_{15} - H\,y\right]\frac{1}{h} = 62{,}600 \text{ pounds}$$

$$\left(\frac{M}{h}\right)'_{15} = \left[R'\,l\ \frac{x}{l-x} - R'_{15} - H\,y\right]\frac{1}{h} = 62{,}600 \text{ pounds}$$

$$D_{\text{I}} = \left(\frac{M}{h}\right)_{15} - \left(\frac{M}{h}\right)_{o} = \left(\frac{M}{h}\right)_{15} = 62{,}600 \text{ pounds}$$

C_{30} *max.*—

Maximum line $g_m = \dfrac{3{,}000}{52} = 57{\cdot}7$

Maximum span $= a + (g_m - a) = 57{\cdot}7$

$$\frac{d\,C}{d\,g} = 25\ W_1 - 13\ W$$

First wheel of engine 50·75 from abutment *A*, last wheel of tender 3·75 from abutment *A*.

Fourth driver in point (30).

$$C_{30}\ max. = \left(\frac{M}{h}\right)_{30} = +\ 1894 + 13{\cdot}8 = 137{,}300 \text{ pounds.}$$

$$D_{\text{II}} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15} = 137{,}300 - 56{,}600 = +\ 80{,}700$$

C_{45} *max.*—

Max. line $g_m = 62{\cdot}5$.

Max span $= a + (g_m - a) = 6{\cdot}25$

$$\frac{d\,C}{d\,g} = 25\ W_1 - 18\ W$$

Third driver of first engine in point 45, last wheel of tender 14·5 feet from abutment *A*, followed by 3,000 pounds per foot for 12·2 feet.

$$C_{45}\ max. = 1{,}818 \div 7{\cdot}8 = 233{,}100 \text{ pounds} = \left(\frac{M}{h}\right)_{45}$$

$$D_{III} = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{30} = + 107{,}000 \text{ pounds.}$$

$C_{60}\ max.$—

$$\text{Max. line } g_m = 68{\cdot}2$$

$$\text{Max span} = a + (g_m - a) = 68{\cdot}2$$

$$\frac{d\,C}{d\,g} = 25\ W_1 - 22\ W$$

First driver of first engine in point 60, second driver of second engine 1·75 from abutment *A*.

$C_{60}\ max.$

$$= 1{,}095 \div 42 = 260{,}600 \text{ pounds} = \left(\frac{M}{h}\right)_{60}$$

$$D_{IV} = \left(\frac{M}{h}\right)_{60} - \left(\frac{M}{h}\right)_{45} = + 52{,}400 \text{ pounds.}$$

Minima (*Top Chord*).

$C_{15}\ minim.$—

$$\text{Max. line } g_m = 53{\cdot}6$$

$$\text{Minimum span} = \left(\frac{l}{2} - g_m\right) + c = 96{\cdot}4$$

$$\frac{d\,C}{d\,g} = 7\ W - 9\ W_3$$

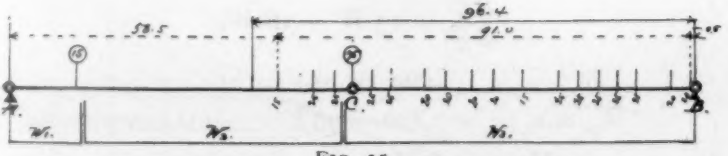


FIG. 15.

To the right of the dividing line (top hinge)

$$W = 400\ W_3 = 310.$$

To the left of the dividing line (top hinge)

$$W = 400\ W_3 = 335$$

Whence

$$\frac{d\,C}{d\,g} = \begin{cases} 2{,}800 - 3{,}015 < o^* \\ 2{,}800 - 2{,}790 > o \end{cases}$$

and with

$$R\,l = 18{,}185$$

$$R'\,l = 41{,}815$$

$$\text{check } R\,l + R'\,l = W\,l = 60{,}000 = 400 \times 150$$

$$R_{15} = o \quad R_{75} = 566 \quad H\,f = R\,\frac{l}{2} - R_{75} = 8{,}526$$

$$H\,y = H\,f\,.\,\frac{y}{f} = 3{,}069$$

$$R'_{15} = 35{,}815$$

$$R'_{75} = 12{,}382$$

$$H'f = R'\,\frac{l}{2} - R'_{75} = 8{,}526$$

$$C_{15} = \left(\frac{M}{h}\right)_{15} = \left(Rl\frac{x}{l} - R_{15} - H\,y\right)\frac{1}{h} = \left(R'l\,\frac{x}{l-x} -\right.$$

$$\left. - R'_{15} - H\,y\right)\frac{1}{h} = -\,1{,}251 \div 22{\cdot}2 = 56{,}400 \text{ pounds.}$$

$$D_{I} = \left(\frac{M}{h}\right)_{15} - \left(\frac{M}{h}\right)_{15} = \left(\frac{M}{h}\right)_{15} = -\,56{,}400$$

C_{30} *min.*—

Minimum span = 92·3

$$\frac{d\,C}{d\,g} = 13\,W - 16\,W_3$$

(See Fig. 15.)

$$C_{30}\ min. = -\,1{,}820 \div 13{\cdot}8 = -\,131{,}900 \text{ pounds.}$$

$$D_{II} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15} = -\,75{,}500 \text{ pounds.}$$

---

* In the same way the positions of the loads are found from $\frac{d\,C}{d\,g}$ for C_{30}, C_{45}, C_{60}, min.

C_{45} *min.:*

Minimum span = 87·5 (see C_{15})

$$\frac{dC}{dg} = 6\ W - 7\ W_3$$

Second driver of first engine on top hinge, first wheel of second tender 0·75 from Abutment *B*.

$$C_{45}\ min. = -\ 1{,}744 \div 7{\cdot}8 = -\ 223{,}500 = \left(\frac{M}{h}\right)_{45}$$

$$D_{III} = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{50} - 92{,}600$$

C_{60} *min.:*

Minimum span = 81·8

$$\frac{dC}{dg} = 11\ W - 12\ W_3$$

First driver of first engine on top hinge, fifth driver of second engine four feet from Abutment *B*.

$$C_{60}\ min = -\ 1{,}086 \div 42 = -\ 25{,}8600 = \left(\frac{M}{h}\right)_{60}$$

$$D_{IV} = \left(\frac{M}{h}\right)_{60} - \left(\frac{M}{h}\right)_{45} = -\ 40{,}600 \text{ pounds.}$$

Bottom Chord:

The full thrust being taken up in the bottom chord, we have

$$C_x = \left(\frac{M}{h}\right)_x - H$$

and

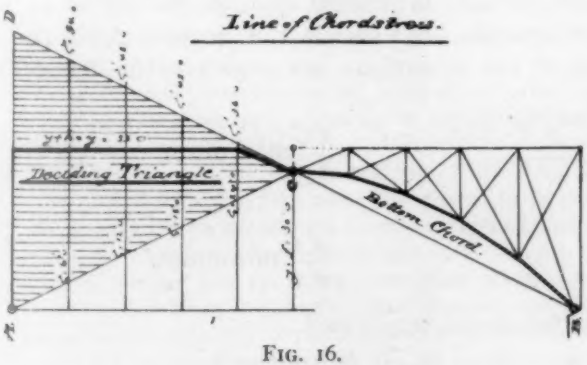


FIG. 16.

x	$\frac{\zeta' - (y+h)}{2f}$	$\frac{\zeta + (y+h)}{2f}$	$\frac{\zeta - (y+h)}{2f}$
15	+ 0·35	+ 0·65	− 0·45
30	+ 0·25	+ 0·75	− 0·35
45	+ 0·15	+ 0·85	− 0·25
60	+ 0·05	+ 0·95	− 0·15
	a	β	c

check a, β, c of top and bottom chord differ by

$$\frac{h}{2f}$$

The general equations of the stresses in the bottom chord are:

$$C_{15} = [0{\cdot}35\ W_1 g_1 + W_2 (15 - 0{\cdot}65\ g_2) - 0{\cdot}45\ W_3 g_3] \frac{1}{22{\cdot}2}$$

$$C_{30} = [0{\cdot}25\ W_1 g_1 + W_2 (30 - 0{\cdot}75\ g_2) - 0{\cdot}35\ W_3 g_3] \frac{1}{13{\cdot}8}$$

$$C_{45} = [0{\cdot}15\ W_1 g_1 + W_2 (45 - 0{\cdot}85\ g_2) - 0{\cdot}25\ W_3 g_3] \frac{1}{7{\cdot}8}$$

$$C_{60} = [0{\cdot}05\ W_1 g_1 + W_2 (60 - 0{\cdot}95\ g_2) - 0{\cdot}15\ W_3 g_3] \frac{1}{4{\cdot}2}$$

Making $c = 0$, we find the maximum line g_m and with it the maximum and minimum span of the stress as in the top chord stresses. As also in the bottom chord the third members of the equations are negative, the same expression for

$$\frac{dC}{dg} \text{ maximum}$$

and

$$\frac{dC}{dg} \text{ minimum,}$$

as for the top chord, are found.

[*To be continued.*]

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, September 20, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 20, 1892.

Dr. Wm. H. Wahl, President, in the chair.

Dr. Bruno Terne read an interesting and valuable paper, giving an account of the meeting of the Association of Agricultural Chemists, held recently in Washington. The paper included an historical account of the association and a critical consideration of the merits of the analytical methods approved by the association for the quantitative analysis of fertilizers. The paper was discussed by the author and Mr. Williams, of Wilmington.

The Section then adjourned. WM. C. DAY, *Secretary.*

PROCEEDINGS.

[*Stated meeting, held Tuesday, October 18, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 18, 1892.

Dr. Wm. H. Wahl, President, in the chair.

The resignation of Mr. G. L. Norris was presented, and on motion was accepted by vote of the Section.

The Treasurer called attention to the name of a member whose dues have not been paid for two years; according to the by-laws the name was dropped from the list of members.

The President proposed for membership Mr. J. Benjamin Glavin, 1312 Passyunk Avenue, Philadelphia; the name was referred to the Committee on Admissions and Mr. Glavin was elected a member of the Section.

The Actuary of the Institute presented two bills from the Institute for subscriptions to various journals. The contraction of these bills having already been authorized by the Section, the bills were ordered paid and they were accordingly submitted to the Treasurer of the Section for payment. The Actuary also requested authority to pay for subscriptions to journals

from February of the present year to date. These bills amounted to a total of 59·40 marks. On vote the necessary authority was granted.

In view of the fact that Dr. Harvey Wiley, of the Agricultural Department, at Washington, is to lecture at the Franklin Institute on the evening of the 5th of December, of the present year, Dr. Terne suggested that it would be fitting for the Chemical Section to tender him a reception after the close of his lecture. The suggestion was favorably considered and on motion the President was requested to name a committee to consider the question of the arrangement and form of the reception; the committee was requested to report at the next meeting of the Section. The President named Dr. Terne, Dr. Jayne and Mr. Pemberton as members of this committee.

Mr. Geo. W. Whyte, of the Camden Iron Works, then read a paper entitled "The Washing of a Southern Coal; Comparison of Laboratory Results with those of Actual Washing Test." The paper gave some valuable results of quite a large amount of experimental work and was listened to with much interest by the members present.

The discussion which followed was conducted by the author, the President and Mr. Pemberton. An abstract of the paper will be published in the *Journal* of the Institute.

Mr. Palmer followed with a note on "A Lilac Color from Extract of Chestnut." Mr. Palmer's remarks were as follows:

"In experimenting with a commercial extract of chestnut wood, with the idea of making galloflavine therefrom, an unlooked-for result was obtained. The extract was somewhat fermented; that is, a part of the tannin had been changed into gallic acid; and the design was to convert this gallic acid into galloflavine by the usual method.

"A solution of the 51° extract was made strongly alkaline with potash, and subjected to the action of a stream of air for about ten hours. The temperature, meantime, was kept below 50° F. At the end of the period of oxidation, the potash was neutralized with acetic acid. The solution so obtained was tested for galloflavine by working therein cotton and wool yarns with the addition of potash alum. While no yellow color was obtained, a clear, bright lilac was developed on both the animal and the vegetable fibre.

"The body giving this color has not as yet been separated from the oxidized extract."

The Section then adjourned.

WM. C. DAY, *Secretary.*

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, September 27, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 27, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, twenty-eight members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the cash balance in the treasury, and presented bills for printing, which were approved and ordered paid.

Ten nominations to membership were referred to the Committee on Admissions.

Mr. C. W. Pike proposed to amend the first sentence of Article IV of the Section's By-Laws by striking out the words *one dollar* and substituting therefor the words *two dollars*, to make the sentence read, "The annual dues of active, corresponding and associate members shall be two dollars, payable annually in advance, on the first of January of each year." [To be acted on at next meeting.]

Dr. Wm. H. Wahl read a paper describing the plant and process used by the Tacony Metal and Iron Company in electro-plating the large ornamental iron-work for the City Hall, with an aluminum alloy. In discussion thereon, Professor Houston stated that if the plating alloy were electro-negative to iron, the practical success of the operation would be very doubtful.

Prof. Edwin J. Houston read a paper on "Some Curiosities in Early Electro-therapeutics." Referred for publication.

Mr. W. N. Jennings exhibited, by projecting lantern, and described, some photographs of lightning taken by him from a rapidly-moving train on the prairie of North Dakota at midnight, August 8, 1892. The first and second, taken broadside from a car window, showed single and double discharges, and telegraph poles in triple outline. The third, taken from the rear platform of the train, showed a single discharge with buildings in quadruple outline. The fourth showed a wonderful discharge in the form of a broad band which was called "sash lightning." All of the photographs seemed clearly to prove that lightning is an oscillatory motion; Mr. Jennings also showed several photographs of "coronal" electric discharges taken in April, 1889; and outlines of Holtz machine sparks, made directly on photographic plates, without the use of a camera. All of these excited much interest and were discussed at considerable length.

The meeting then adjourned. L. F. RONDINELLA, *Secretary.*

On POLYPHASED CURRENTS.

By Paul A. N. Winand.

[*A paper before the Electrical Section, at the stated meetings of April and May, 1892.*]

[*Concluded from p. 330.*]

A MECHANICAL ILLUSTRATION OF POLYPHASED CURRENTS

Before going over to the comparison of the amounts of copper required in line for the transmission of power by means of continuous, alternating and polyphased currents, and to the question of measurement of energy, it may be interesting to describe a simple mechanical model by means of which most of the preceding considerations can be shown in a tangible manner. It consists (*Fig. 11*) in two discs (shown as rings of wire with spokes) mounted in such fashion that they can rock, without being allowed to turn, on their centres. Each disc is provided with a small central shaft perpendicular to its plane. A small crank is so connected to one of the shafts as to impart to it a circular conical motion around the main axis of the apparatus, which is the line joining the centres of the discs. The discs, in order to be prevented from rotating, may be connected to the frame by flat springs, or by strings (as shown), secured to their periphery and to a point of the frame situated at same level as the centre of the disc. When the crank is turned the first disc rocks evenly in all directions, and each of its points has an almost straight up and down motion, which follows the *sine* law very closely; but the different points of the periphery reach their extreme positions successively. Their motions are of different phases.

If strings of equal lengths are stretched from corresponding points of the peripheries from one disc to the other, they will have longitudinal motions following the *sine* law, and will represent the different currents (or electro-motive forces) of a polyphased system.

The second disc, with its shaft, will follow exactly the motions of the first.

Fig. 11 corresponds to a symmetrical five-phase system. Any system, however, can be represented by securing the strings to corresponding points (not only at the periphery) of the discs. The second general condition of polyphased currents is expressed, in the model, by the mechanical analogon: that the centre of gravity of the strings must be on the main axis.

With a slight modification the same model can exhibit the relations between star and mesh currents.

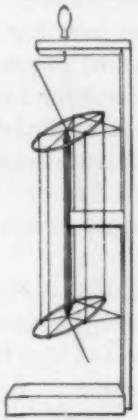


FIG. 11.

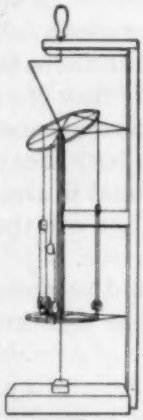


FIG. 12.

Fig. 12 shows this for a symmetrical three-phase. Each string from the first disc carries at its end a small pulley. A continuous string (mesh string) is led over these pulleys and over others fastened to the second disc. If now the axis of the latter be held stationary in the main axis while the crank is being operated, the first named pulleys will move up and down with the star strings, and the mesh string will have a motion of its own, which is different in phase in the different sections of this string, and also different from the motions of the star strings.

In each section the motion corresponds in phase with the current in the corresponding branch of the mesh combination, but its amplitude is double as compared with the motions of the star strings.

EFFICIENCY OF TRANSMISSION AND AMOUNTS OF COPPER.

The comparison in respect to the efficiency of transmission for a given line or to the amounts of copper required for obtaining the same efficiency, has often been made between the alternating and the continuous systems.

We might, therefore, confine ourselves to comparing the plain alternating with the polyphased systems. I will, however, recall concerning the continuous system, that the same current (measured in both cases with a dynamometer) gives the same loss by heating in the same wire whether it be continuous or alternating, as long as the frequency is not so high as to produce an appreciable skin effect.

If the alternations follow the same law for current and potential, and if there is no difference of phase between the two, the rate of flow of energy is the same for continuous and alternating transmission when current and voltage are the same and are both measured with instruments giving readings proportional to the *mean square*.

The same line will then produce equal losses and efficiencies in both cases.

But it should be remembered that, if the *sine* law is followed, when the measured voltages are the same, the *maximum difference of potential* is $\sqrt{2}$ times as large in the alternating than in the continuous transmission. Accordingly it requires twice as much copper to transmit, with the same efficiency, a given energy by alternating than by continuous currents, if the same *maximum* difference of potential is to be allowed in both cases.

It has been claimed by competent men that as far as insulation and danger are concerned, a higher *maximum* difference of potential is allowable on alternating circuits, the more so the higher the frequency. To what extent this is the case appears to be undecided yet, but it seems fair to assume that, for usual frequencies, the *measured* alternating voltage which corresponds to 100 volt continuous is comprised between

$$100 \text{ and } 70{\cdot}7 \left(\text{or } \frac{100}{\sqrt{2}}\right)$$

and that consequently the amount of copper required is larger

for alternating than for continuous transmission, though less than twice as large.

Whatever this proportion may really be, as everything is alternating in the polyphased systems, these doubts do not apply to the comparison between plain alternating and polyphased transmission. A difference of phase between current and electro-motive force, which would necessitate an increased amount of copper in the alternating transmission, would be just as disadvantageous in polyphased currents and would not change the relative values obtained for these two systems.

Everything being alternating, it might seem, at first, that there is no difference in the amounts of copper required for alternating or polyphased transmission with a given efficiency.

In reality, however, the polyphased systems are, gen-

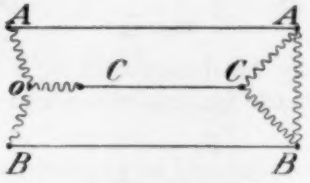


FIG. 13.

erally, more advantageous (the three-phase especially so), and this is due, broadly speaking, to the fact that the voltage on which the energy depends is not always the same as the voltage which has to be considered for insulation.

Fig. 13 represents a symmetrical three-phase, one end being a star, the other a mesh combination. *A-A*, *B-B*, *C-C* are the line conductors If we call V_e the voltage between *O* and *A*, and C_1 the current (square root of mean square) in *AA*, we have seen previously that the voltage V_1 between *A* and *C* for instance is

$$V_1 = 1{\cdot}73\ V_e \qquad (1)$$

and the current in *AC* is

$$C_m = 0{\cdot}577\ C_1$$

It is obvious that the voltage which should be considered

for insulation is V_1, because it is the highest that occurs between any two points of the system.

But the voltage on which the energy depends, together with the current C_1 in the line, is V_e.

The total energy is

$$E_3 = 3\ V_e\ C_1 \tag{2}$$

and if R_3 is the resistance of each line conductor, the total loss in transmission is

$$H_3 = 3\ C_1^2\ R_3 \tag{3}$$

For a plain alternating or two-phase system (*Fig. 14*), the

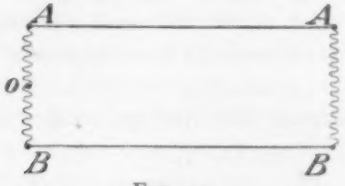


FIG. 14.

voltage $A\ O\ B$ may be designated by $2\ V$, and there is no distinction to be made for insulation and energy.

$$E_2 = 2\ C\ V \tag{4}$$

$$H_2 = 2\ C^2\ R_2 \tag{5}$$

The alternating and three-phase are of same practical voltage when

$$V = 2\ V \tag{6}$$

Substituting (1) in (6) gives

$$2\ V = 1{\cdot}73\ V_e \tag{7}$$

or

$$V_e = 1{\cdot}154\ V$$

For comparing the cases where the same energy is to be transmitted with the same efficiency, we have to equalize (2) and (4); and this, with (7), gives

$$C = 1{\cdot}73\ C_1 \tag{8}$$

In the line, the currents are 1·73 times as large in alternating than in three-phase.

Equalizing (3) and (5) gives, with (8),

$$R_3 = 2\,R_2$$

This means that the cross section of alternating line conductor is twice that of three-phase conductor, and that the total amounts of copper are as 4 for alternating to 3 for three-phase.

This result, in combination with the erroneous assumption that the alternating system is as advantageous as the continuous, has led to the wrong conclusion that the three-phase is more advantageous (for equal voltage) than the continuous transmission.*

If we compare the cases in which the current density is the same for both, then

$$R_3\,C_1 = R_2\,C$$

and substituting (8) in this

$$R_3 = 1{\cdot}73\,R_2 \qquad (9)$$

which, with (3) and (5), gives

$$\frac{H_3}{H_2} = 0{\cdot}866$$

The percentages of loss are as 0·866 in the three-phase to 1 in alternating when the drop of potential along the line is the same.

(9) shows that then the amounts of copper are also as

0·866 to 1

The three-phase is, respecting economy of copper, more advantageous than any other polyphased system.

Whenever the number of phases is *even*, say $2n$, the system can be considered, as far as voltage and energy are concerned, as composed of n distinct ordinary alternating currents, by taking any two diametrically opposite currents together.

---

* This comparison relates only to the expenditure of copper for a given voltage, leaving altogether untouched the question of obtaining or dealing more or less easily with high voltages.

The amount of copper needed is, in this case, the same as for plain alternating transmission.

When the number of phases is *uneven* there is a saving in copper, but it is the smaller the higher this number is.

So while it is twenty-five per cent. for the three-phase, it is but 9·5 per cent. for the five-phase, and so on.

The four-phase (often called two-phase) gives no saving over the alternating, as the number of phases is even, when it is used in the symmetrical manner, with four conductors.

When it is worked by means of three conductors (one being a common return, in the well-known manner), the system is unsymmetrical and the amount of copper required is even greater, as will appear from the following:

In *Fig. 15*, *OO* represents the common return wire of such a system.

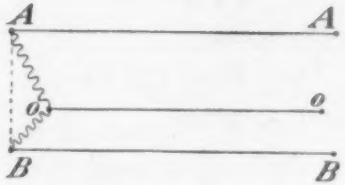


FIG. 15.

Let V_{4e} be the voltage between O and A, and V_{41} the voltage between A and B, then, as the currents in OA and OB are at

$$90° \text{ or } \frac{\pi}{2}$$

difference of phase and the differences of potential also. This latter, taken between A and B, will differ in phase by

$$\frac{\pi}{4} \text{ and } \frac{3\pi}{4}$$

from those in OA and OB and

$$V_{41} = 2 \sin \frac{\pi}{4} V_{4e}$$

or

$$V_{41} = \sqrt{2}\, V_{4e} \qquad (10)$$

Correspondingly the currents stand as

$$C_5 = \sqrt{2C_4} \qquad (11)$$

if C_4 is the current in AA or BB and C_5 the current in OO. The energy is

$$E_4 = 2V_{40}\, C_4 \tag{12}$$

and the loss

$$H_4 = 2C_4^2\, R_4 + C_5^2\, R_5 \tag{13}$$

If we assume the same current density in wires A, B and O, then

$$R_4 = \sqrt{2}\, R_5$$

which, with (11) and (13), gives

$$H_4 = 2C_4^2\, R_4 + \frac{2}{\sqrt{2}}\, C_4^2\, R_4$$

or

$$H_4 = (2 + \sqrt{2})\, C_4^2\, R_4 \tag{13a}$$

In order to compare this result with alternating transmission we have to assume

$$V_{41} = 2V$$

and equalize (4) and (12), (5) and (13*a*), this, together with (10), gives ultimately

$$R_2 = \frac{2 + \sqrt{2}}{4}\, R_4$$

The distance of transmission being supposed to be the same, the weight of each conductor is in inverse proportion to its resistance, and the total weights are as

$$8 \text{ to } (2 + \sqrt{2})^2$$

or

$$1 \text{ to } 1{\cdot}457$$

for alternating and four-phase.

As a conclusion of the preceding calculations, if the amount of copper required in the line when the same practical voltage is used and under otherwise identical conditions is 100 for alternating current, it would be 75 for three-phase, 90·5 for five-phase, 70·7 to 100 for continuous, 100 for four-phase when symmetrical, and 145·7 for four-phase with common return wire.

The last named system requires, consequently, almost twice as much copper as the three-phase.

If there is a difference of phase between the currents and potentials, the carrying capacity of the conductors in respect to energy is reduced as the square of the cosine of the difference of phase. But this applies to the alternating as well as to the polyphased systems.

It appears from all the preceding considerations, I think, that the three-phase has decided advantages over the other polyphased and the alternating systems, and I will, therefore, confine my further remarks to the three-phase.

Calculations similar to the above might be carried out for determining the relative losses and the weights of copper in case of a non-symmetrical system. This would, however, be of little practical interest.

MEASUREMENT OF ENERGY.

I shall now touch the question of measurement of energy in the three-phase, but in this respect it is of actual value to consider also the general case of a non-symmetrical system having any differences of phase between the currents and potentials.

When the system is symmetrical the energy is

$$E = 3\ V_e\ C_1\ cos\ \varphi$$

or

$$E = 3\ V_1\ C_m\ cos\ \varphi$$

In this case, one reading of a dynamometer gives directly the energy, but the instrument cannot generally be connected so as to give one of these results
as

$$V_1 = \sqrt{3}\ V_e$$

the energy is also

$$E = \sqrt{3}\ V_1\ C_1\ cos\ \varphi$$

This formula enables to work with the instrument using the current in the line and the voltage between two line conductors.

As a rule, however, the system cannot be relied upon to be symmetrical.

Messrs. Siemens & Halske have devised a method and constructed an instrument for measuring the energy in this case.*

If the currents in the three line wires are of same magnitude, then by connecting an ordinary dynamometer so that one line current, say in AA, is used, while the volt coil is connected first to A and B, then to A and C, two readings are obtained, whose sum is the total energy.

Their special dynamometer gives this same result in one reading. Its volt coil consists of two separate windings which are connected to A, B and B, C.

If the three voltages, AB, BC and CA, were the same, instead of the three currents, and this is more likely to be the case in practice, the same result would be obtained by a dynamometer provided with a double current coil and a simple volt coil.

Mr. Goerges points out that if the two above-named readings of an ordinary dynamometer are equal, this shows in the present case that there is no difference of phase between current and potential.

He shows further that the energy of any unsymmetrical three-phase can be obtained by six readings on an ordinary dynamometer or by three on the special Siemens instrument.

The above results, as well as a less complicated method, can be established by means of a very simple consideration, which proves useful also in other cases, namely:

> That any three-phase system can always be considered as consisting of two partly superposed independent alternating currents.

One is the current which passes through one line conductor, say AA, and flows back through the two others as a common return.

---

* See the paper of Mr. H. Goerges, chief engineer of this firm, in *Elektrotechnische Zeitschrift*, 1891, p. 212.

The second is superposed to the former in the two other conductors and does not affect the current in the first conductor.

Its value is, at any time, half the difference of the currents in *B* and *C*, while the value of the first is equal to minus half their sum.

The energy of the first is, at any moment, equal to the product of current *A* and the mean difference of potential between *A* on one side and *B* and *C* on the other; that is, half the difference of the differences of potential β and γ between *A C* and *A B* when taken with their proper signs.

It is twice this part of the total energy which is measured

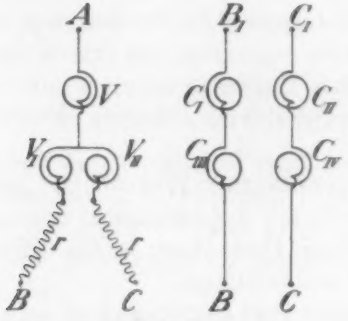


FIG. 16.

by the special Siemens dynamometer when connected as above.

The energy of the second is equal to the product of half the difference of the currents *B* and *C* and the difference of potential *a* between *B* and *C*.

The first part of the energy can also be measured by means of an ordinary dynamometer, whose current coil carries the current *A* while its volt coil is connected to *A* and to the middle of a resistance stretching from *B* to *C*. This resistance need not even be non-inductive, provided its two halves be equivalent.

The second part can be measured by a dynamometer which has a double current coil.

Such an instrument could easily be so arranged as to enable to measure also the first part with a proper change

of connections. The total energy would then be given by two readings.

This result expressed by formulas is

$$E = A\left(\frac{\beta - \gamma}{2}\right) + \left(\frac{C - B}{2}\right) a \qquad (13)$$

which is true as well for the instantaneous values as for their integral or the energy for one unit of time.

It is possible, however, to make an instrument which will combine the actions of these two parts of the energy so as to give directly their sum or the total energy.

Fig. 16 is a diagram showing the working of such an instrument. The part on the left, which may be the movable one, contains one simple volt coil V and a double one,

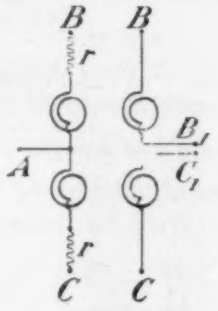


FIG. 17.

V_I V_{II}, the two halves of which are wound in opposite directions, and are connected to the equal resistances, r r.

The part on the right contains two double current coils. The halves, C_I C_{II}, of the upper one are wound both in the same way and act on coil V only.

The action is proportional at any moment to the sum of the currents B and C, or to current A.

The two halves, C_{III} C_{IV}, of the lower coil, are wound or connected in opposite directions, and act only on coil V_I V_{II}.

V_I and V_{II} being of opposite directions give no resultant action for the current which flows in V, but their actions are added for the current flowing from B to C through the

resistances r r in consequence of the difference of potential, a.

Dr. H. Aron has devised another method which is simpler yet, as it requires an instrument with four simple coils, acting in pairs, according to the diagram, *Fig. 17*.

He has modified his well-known pendulum watt counter, according to this principle, for use on three-phase circuits.

He has established this principle* by a very simple calculation, which I reproduce below.

If a, b, c represent the instantaneous values of the mesh

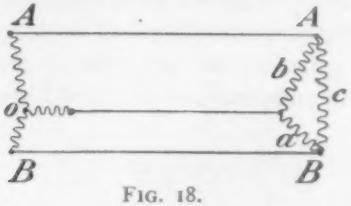


FIG. 18.

currents, *Fig. 18*, and A, B, C; α, β, γ the same as before, then at any moment the total rate of flow of energy is

$$E = a\alpha + b\beta + c\gamma \qquad (14)$$

The second condition of polyphased currents (in this case simply Kirchhoff's law) gives for three-phase

$$a - c = B \qquad (15)$$

$$b - a = C \qquad (16)$$

and the third condition

$$\alpha + \beta + \gamma = O \qquad (17)$$

If we subtract the identical expression

$$a(\alpha + \beta + \gamma) = O$$

from (14) we obtain

$$E = \beta(b - a) - \gamma(a - c)$$

which, by substituting (15) and (16), becomes:

$$E = \beta C - \gamma B$$

The two products in this equation represent the instantaneous actions of the two pairs of coils in *Fig. 17*.

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* *Elektrotechnische Zeitschrift*, 1892, p. 193.

It does not seem very natural to substract

$$a(\alpha + \beta + \gamma) = O$$

from (14), but the result can be reached equally well by writing instead of (15) and (16)

$$b = C + a$$

and

$$c = a - B$$

and substituting these values in (14), this gives:

$$E = a\,\alpha + C\,\beta + a\,\beta + a\,\gamma - B\,\gamma$$

$$E = a\,(\alpha + \beta + \gamma) + C\,\beta - B\,\gamma$$

$$E = C\,\beta - B\,\gamma$$

The same result can also be obtained by substituting in the previous equation (13)

$$A = -(C + B)$$

$$\alpha = -(\beta + \gamma)$$

which are but other expressions of the second and third conditions, this gives

$$2\,E = (C + B)\,(\beta - \gamma) + (C - B)\,(\beta + \gamma)$$

$$= C\beta + B\beta + C\beta + C\gamma - B\gamma - C\gamma - B\beta - B\gamma$$

$$2\,E = 2\,C\beta - 2\,B\gamma$$

We see thus that the measurement of energy in the three-phase system, which is likely to be the only one to come into extensive use, can be effected by one single reading of an instrument almost as simple as those used for the same purpose on ordinary alternating circuits.

The result is perfectly accurate and independent of whatever the currents and their phases may be and of however much these may differ from the phases of the electromotive forces.

For that reason the same instruments can be applied to the measurement of energy in the unsymmetrical four-phase, with three conductors (*Fig.15*), which may be considered as a special case of the general three-phase system.

SOME CURIOSITIES IN EARLY ELECTRO-THERAPEUTICS.

BY PROF. EDWIN J. HOUSTON.

[*Read before the Electrical Section of the Franklin Institute, September 27, 1892.*]

The astonishing physical effects produced by the discharge of the Leyden jar through the human body, led not only the general public, but also the medical fraternity, shortly after its discovery in 1745, to form the most absurd ideas concerning the curative powers of electricity.

The wildest claims were made concerning the efficacy of the electric discharge for the curing of disease. Claims that were at first unhesitatingly accepted as true were soon found in actual practice to fail of realization.

That *bona fide* results in the way of actual cures were obtained in some of the early applications of electricity to the curing of disease appears to be beyond doubt, for the method of treatment in some cases remains practically the same to-day as it was at the time of the discovery of the Leyden jar. Then, again, in those days, as at present, the public's natural credulity led it to perhaps lay more stress on the few cases that were cured than on the more numerous cases that either failed to receive any benefit from the treatment or were actually killed by it; or, putting the same thing in another way, the people who were cured gave glowing certificates of their cures, while the people who were killed gave none.

I have thought that it might interest you if I brought before you a few curiosities in the way of the astonishingly absurd statements that were put forth about the time of the discovery of the Leyden jar, as to the ability of the electric force to cure.

Unfortunately, I have been called upon to read this paper at an extremely short notice, and must, therefore, ask you to take, in many cases, my recollections of matters that I

have read a number of years ago, in place of actual quotations from the original records.

Far be it from my purpose to throw any discredit on the medical fraternity as it existed in the latter part of the eighteenth and the beginning of the nineteenth century, or to throw any doubts on the value of electro-therapeutics as practised at the present day; for the great value to be derived from the intelligent application of electricity for curative purposes is no longer a matter of doubt.

In criticising some of the ideas presented in electro-therapeutics, at the time of the discovery of the Leyden jar, it should be remembered that it is, of course, much easier to find fault with methods than to propose better methods; and when we remember the comparatively limited knowledge the world had acquired concerning the nature of the electric force at these early times, and the belief that was quite common in the scientific world concerning the presence of various effluvia, which were supposed to be capable of passing through the densest matter, we should criticize less harshly some of the beliefs put forward at these early times as to the proper method of applying electricity to the curing of disease. Indeed, an examination of the advertisements of some so-called medical electricians made even in these latter days, would unearth absurdities far more marked than those of the time we are discussing.

I once read in a circular letter issued, if my memory serves me correctly, some fifteen years ago, by a certain so-called medical doctor, in which he claimed among other advantages for the peculiar kind of electricity which he claimed his apparatus was capable of producing, that it was electricity of the corkscrew or gimlet type, and that it, therefore, had but little difficulty in insinuating itself into all parts of the body, so searching out the disease. Or, taking a time not so modern, when a certain inventor, I think, by the name of Edward Craddock Monckton, an exceedingly ingenious man by the way, who has taken out scores of electrical patents, and among others a method of electrically joining articles of jewelry, gravely proposes in

a British patent, to so connect the body of a healthy animal, like a cow for example, with that of the patient to be treated, as to electrically convey the health and strength of the animal to the patient. To do this he places the body of the cow, or other animal, upon an insulating stool, and connecting it to that of the patient to be treated by electric conductors, passes the current of a battery through the animal and subsequently through the body of the patient and thereby, as he claims, conveys to the patient the vitality of the animal.

Passing these aside, however, I would call your attention to a few curiosities in early electro-therapeutics.

It was believed by many of the early practitioners that the virtues of a drug could be readily caused to pass through glass vessels by means of electric discharges. This belief was probably founded on the rather prevalent belief at this time as to the existence of effluvia. The attraction of a magnetic needle by a magnet, notwithstanding the interposition of a plate of glass, was at one time explained on the supposition of effluvia passing out of the magnet and through the glass into the iron. It is not, therefore, surprising to find such statements as that of a Dr. Bruni writing to Dr. Watson of a remarkable case in which, as he claims, medicine shut up in a tightly sealed glass globe produced its peculiar effect on a person who was electrified by the use of said globe. I mention this as a particular case, although the early records of electricity are filled with similar cases. What Dr. Watson has to say about these experiments will, I think, interest you, and I will, therefore, give you the following quotation:

"Dr. Bruni gives me next in his information from Rome, which is, that a gentleman there covered the internal surface of a glass cylinder (which some use instead of a globe) with a purgative medicine; and that man, electrified therewith, found on the spot the same effect as if he had swallowed the medicine. He then recommended to us, in England, to try how far the electric power may be of service in distempers.

"These cases, and particularly the last, as it may to some

appear extravagant and whimsical, I should have been cautious of bringing before the Royal Society, had you not judged it proper they should be added to those similar accounts from other places, which were read to us last meeting. I think neither myself nor Dr. Bruni answerable for the truth of these facts, as we relate no more than we have received. In truth, all the phenomena in electricity are so wonderful that it is scarcely prudent to deny the possibilities of any accounts concerning it till we have made experiments carefully ourselves. We are very sure it is possible to render a living body replete with electrical effluvia, or to transmit and send such effluvia through a living body, in a stream, as long as we think proper: we are not sure that it is impossible for these effluvia to convey with them into that living body the most subtile and active effluvia of other substances; and if they can do so, the effects suggested are not wholly improbable, for several experiments have proved that a very minute quantity of medicine, transfused directly into the blood and circulating fluids, will have the same effect as a large dose thereof taken into the stomach."

Somewhat similar to the effect just referred to was the belief that the odors of certain substances, placed in tightly sealed glass globes, could be detected by sending electric discharges across them; or the similar belief that highly poisonous substances, placed in such glass globes, could produce deleterious effects on people when electric discharges were sent through the glass globes.

In the *Encyclopedia of the Arts and Sciences*, published in 1798, the following account is given of the so-called medicated tubes:

"It was asserted by Signor Pivati at Venice, and after him by Verati at Bologna, Mr. Blanchi at Turin, and Mr. Winkler, at Leipsic, that if odoriferous substances were confined in glass vessels, and the vessels excited, the odors and other medicinal virtues would transpire through the glass, infect the atmosphere of the conductor, and communicate the virtue to all persons in contact with it; also, that those substances, held in the hands of persons electrified, would communicate their virtues to them; so that the

medicine might be made to operate without being taken into the stomach. They even pretended to have wrought many cures by the help of electricity applied in this way. To see the wonderful effects of these medicated tubes, as they were called, Mr. Nollet travelled into Italy, where he visited all the gentlemen who had published any account of these experiments. But tho' he engaged them to repeat their experiments in his presence, and upon himself; and though he made it his business to get all the information he could concerning them, he returned fully convinced, that in no instance had the odors been found to transpire through the pores of excited glass, and that no drugs had ever communicated their virtue to people who had only held them in their hands while they were electrified."

Franklin made a study of the effects of the so-called medicated tubes. In his *Experiments and Discoveries in Electricity*, published in London in 1769, he says on page 82:

"Hence we see the impossibility of success in the experiments proposed, to draw out the effluvial virtues of a non-electric, as cinnamon for instance, and mixing them with the electric fluid, to convey them with that into the body, by including it in the globe, and then applying friction, etc. For though the effluvia of cinnamon and the electric fluid should mix within the globe, they would never come out together through the pores of the glass, and so go to the prime conductor, for the electric fluid itself cannot come through; and the prime conductor is always supplied from the cushion, and that from the floor. And besides, when the globe is filled with cinnamon, or other non-electric, no electric fluid can be obtained from its outer surface, for the reason before mentioned."

In an article entitled "A New Discovery of the Usefulness of Electricity in Medicine," by John Henry Winkler, read before the Royal Society by Mr. Watson, March 31, 1748, and published in abstract on page 399 of Vol. X of the *Philosophical Transactions*, we find the following statement:

"Electricity has a power of dividing subtilely. It carries off with it the parts of those bodies which it dissolves, and transfers them to those parts where the electrical sparks

appear. If odorous substances are ever so closely confined in glass vessels, it so divides them that their exhalations penetrate the glass as easily as magnetical powers, and flow like a river thro' the atmosphere of cylinders and chains, to which the electricity is communicated. The electrical matter which comes out of the extremity of the cylinder, gives an aromatic odor to the hand that touches it. But the odor communicated does not stop in that part of the body on which the electrical river has flowed, but with a continued aspiration pervades the whole human body. Not only the skin and garments are scented, but even the air breathed by the lungs, the spittle, and the sweat of the person affected smell of aromatics, which are agitated by electricity in the closed vessel."

So also the following account of a similar use on page 400 of the same *Transactions :*

"About the beginning of the present year, 1748, I received a letter from Venice, which greatly confirms this conjecture. The author, Joannes Daniel Gaifel, related an affair which surprised all the learned of Venice, Bologna and other cities of Italy. It was accompanied with a printed epistle in Italian, written by an eminent person at Venice, Sig. Jo. Franc. Pivati. In this epistle, the subject of which is medical electricity, he relates a story of wonderful effects to Sig. Fr. Maria Zanotti, Secretary of the Academy at Bologna; and the art, by which these were performed, was the invention of Pivati. A manifest example of the virtue of electricity was shown in the Balsam of Peru, which was so concealed in a glass cylinder, that before the application of electricity there could not be the least smell of it by any means discovered. A man, who having a pain in his side, has applied hyssop to it by the advice of a physician, approached to the cylinder. The man was electrified by it, went home, fell asleep, sweated, and dispersed the power of the balsam. His clothes, bed, chamber, all smelt of it. When he had refreshed himself by this sleep, he combed his head, and found the balsam to have penetrated his hair, so that the very comb was perfumed. The next day S. Pivati electrified a man in health after the same man-

ner, who knew nothing of what had been done before. On his going into company about a quarter of an hour afterwards, he found a gradual warmth diffusing itself through his whole body. He grew lively and more cheerful than usual, His companions were surprised at an odor, and could not imagine whence it proceeded, but he himself perceived that the perfume arose from his own body, at which he was much surprised, not having the least suspicion that it was owing to the operation that had been performed upon him by S. Pivati."

Another equally curious early practice consisted in the use of what might be termed medicated Leyden jars, in which the inner coating of a Leyden jar, through which discharges were given, was formed of or contained liquids, consisting of aqueous solutions of various medical substances. On the discharges from such jars being passed through a patient's body, it was believed that the peculiar effects of the medicine dissolved in the liquid placed inside the jar could be experienced.

Of a similar nature is a rather extended belief which existed at one time as to the effects produced by sending electric discharges through solutions of medicine prior to their being taken into the system,

In a British patent, 991 for 1862, Frederick William Breary describes improvements in medicated cups, which consist practically in sending electric currents through the medicines contained in such cups prior to their being taken into the body. I will quote from the specification of this patent:

"The third improvement of my said invention consists in the formation of similar cups or vessels in and by which the principle of galvanic action is obtained either in combination with the medicinal qualities above mentioned or otherwise. The drinking vessel formed upon this principle I denominate the improved medicated 'galvanic cup.'

"In applying the above-mentioned improvement to my said invention, I make a cup or other suitable vessel (for drinking or other purposes), also in two or more parts, and either form the same on either of the medicated principles

above described, or otherwise, as may be required, and to fix or insert therein a voltaic or galvanic pile, and galvanize or medicate the water or other liquid placed therein by slightly acidulating the same. By preference, however, I form the foot, stem, and outer bowl of these cups or vessels of glass, china, or other non-conducting material; having three or more water tight cells or compartments therein, separated one from the other. I make the centre compartment occupy nearly the whole of the internal space, and make the two side compartments small, but sufficiently large to contain the galvanic media. The latter compartments are closed at the top by means of movable stoppers; the central compartment is made open for containing the medicated water or other liquid to be galvanized. The internal surfaces of the central compartment I line with metal or mineral on one part, and with wood or vegetable, as before described. Extending across this compartment, and forming a metallic connection between the two side cells, I fix a bar or perforated plate of metal. When using this galvanic cup, the water or other liquid is first placed in the centre compartment, where it is medicated; then by filling the side compartments, one with granulated copper and fine sand, and the other with granulated zinc and fine sand, and adding to each a little acidulated liquid, the galvanic essence will pass or flow along and over the metal bar or perforated conductor through the medicated water or liquid, and will impart its medicinal virtues to the same, and thus a combined medicated and galvanized action will be obtained."

BOOK NOTICES.

The Chronicle Fire Tables for 1892. A record of the fire losses of the United States and Territories during 1891, etc. Royal, 8vo, 341 pages. New York: The Chronicle Company, Limited. Price, $5.

These data, now a standard publication, have become exceedingly valuable to underwriters, manufacturers, merchants and others from attention to the details of fire losses, averages, etc., and conscientious exactness in compilation. An idea of the labor expended on this work is obtained from two sentences of the preface: "To procure nearly 40,000 reports of properties burned, to estimate the loss in each case as closely as obtainable data will permit, to place the record of these losses on separate cards, to arrange and rearrange these cards, in order to prepare the various tables which appear on the following pages, is a work of no small proportions." * * * "A search for the exact truth, touching the loss by every fire, is industriously carried on by the publishers of the *Fire Tables*, upon a system which appears to be the best that can be employed."

A list given of the largest fires during 1891, in the United States, shows fifty-one such, ranging in losses from $200,000 to $1,556,948; and there is a comparison of fires of 1890 and 1891 by classes of property, such as dwellings, wholesale and retail stores, manufactories, hotels, theatres, etc., together with percentages of such classes to the whole number of fires. The great tabulation (pages 12 to 32 inclusive) gives with detail every kind of property attacked by fire in 1891, in the United States, with property loss and insurance loss and the causes of fires. If this were the only tabulation in the book it would be well worth the price; but there is much more that is almost equally valuable.

A tabulation extending from pages 34 to 156 inclusive gives the fire losses in each State and Territory by classes of risks, and one (pages 157 to 228 inclusive) shows the fire losses in 1891 by causes. The latter will be most useful to those studying fire insurance data, and to actuaries and statisticians. There is appended a summary of fires from sixty principal causes—including the one great cause "unknown" and the causes "not reported." A part of the mission of this standard publication is to diminish the number of fires in the last two items; in other words, to increase the accuracy of a knowledge of the causes of fires. There are other tabulations in this volume extending over 104 pages, especially one of sixty-six pages, giving monthly losses by States and Territories—and summaries of fires, causes and losses by (in) certain classes of risks. Two illustrative diagrams accompany this portion.

The feelings with which we close this volume are mingled admiration and satisfaction, that such permanent and reliable fire data are collected and published in the United States. We know of nothing equal thereto in Europe. The advantage of the study of such data is to discover, more and more, the

true causes of ignitions, and to apply remedies more intelligently. There has been much progress in this effort during the past decade, in which laudable design for the public benefit the *Chronicle Fire Tables* have materially aided. N.

A Text-Book on Retaining Walls and Masonry Dams. By Mansfield Merriman, Professor of Civil Engineering in Lehigh University. New York: John Wiley & Sons. 1892.

Professor Merriman here presents, in his now well-known concise and scholarly manner, the principles underlying the construction and behavior of walls and dams, or, rather, certain views, more or less widely accepted, respecting those principles; and thus adds still another to the now considerable number of excellent standard works on engineering subjects for which we are indebted to his pen.

With the exception of the theory of the equilibrium of cohesive earth presented in the first chapter, and deduced from the works of continental writers, the present volume makes no pretension to novelty of matter or of treatment. Like the other works of the author, it confines itself chiefly to placing before us, in convenient form, the recognized or accepted laws governing the subjects treated of.

In view of the uncertainty in which the present subject is shrouded (an uncertainty affecting not only the conditions which may obtain in any particular case, but the very foundations of the theories themselves) the average reader may be inclined to wonder at even the moderate display of mathematical pyrotechnics in which our author here indulges; and to ask whether such labors are remunerative, in view of the well-known fact thus stated by the author on pages 52 and 53, respecting that most important factor, the resultant P of the pressures upon the wall:

"Unfortunate, indeed, it is, that the theory of earth pressure is not sufficiently explicit to determine the exact value and direction of P. He who believes the theory of Article 8 must conclude that this wall is in a very dangerous condition, and almost about to slide; he who defends the theory of Article 9 might conclude that it is not in great danger, and that the degree of security is fair. It is well, however, not to forget that the given data are liable to variations fully as serious as the defects in the theory. Imagine a heavy rainfall to increase W and decrease ϕ; this causes P to become larger, and as F usually would be smaller in wet weather it is seen that the degree of stability of the wall will be greatly diminished. If the factor of security be computed for both theories, as is done above, and the variation in the data be regarded, a fair conclusion can generally be made regarding the security of the wall. The effect of the variable data is often so great that a ripe judgment based upon experience may be more reliable than computations."

The work appears to be confined exclusively to the statement and demonstration of the *precepts* pertaining to the subject; and that this has been admirably done the author's name is sufficient guarantee. We fail to notice,

however, a single citation of an *example* from actual practice, a fact which leads us to wonder at the selection of the motto upon the title-page: *In scientiis ediscendis prosunt exempla magis quam præcepta.* T.

Dynamometers and the Measurement of Power. A Treatise on the Construction and Application of Dynamometers; with a Description of the Methods and Apparatus employed in Measuring Water-Power. By John J. Flather, Ph.B., M. M. E. New York: John Wiley & Sons. 1892.

In spite of a somewhat conspicuous absence of that attention to logical sequence in the arrangement of matter, which goes so far to the making of a thoroughly satisfactory introduction to a subject hitherto unknown to the reader, the present little volume will, we think, be found of great use to those desiring to form some acquaintance with the matters here discussed.

After commenting upon the losses entailed by ignorance of the extent to which power is consumed by the various functions of any given set of machinery, and after presenting the fundamental formulas underlying the subject, the author proceeds to a description of known forms of dynamometers, ancient and modern, covering a large number of machines of the various well-known types. In the main these are well and sufficiently illustrated, and (with the reservation already made) satisfactorily explained. Among the forms described, those of our late member, Mr. Robert Briggs, and of our ex-President, Mr. Wm. P. Tatham, are of course not overlooked, while a hydraulic dynamometer designed by the author is modestly placed at the end of the list.

A short chapter is devoted to the power required for driving lathes, showing that this power varies considerably more than is popularly supposed, and the volume concludes with a résumé of the methods in use for the measurement of flowing water and of contrivances specially adapted to the testing of hydraulic motors.

The index is perhaps ample for a work which, like this, treats of a single subject. T.

Johnson's Tables. Stadia and Earth-work Tables. Four-plate Logarithms. Logarithmic Traverse Table, Natural Functions, Map Projections, etc. Re-printed from Theory and Practice of Surveying. By J. B. Johnson, Professor of Civil Engineering, Washington University, St. Louis. New York: John Wiley & Sons. 1892.

As indicated by the title, this is a reprint from the author's standard work on surveying which has already been noticed at length in these pages, and the tables are chiefly counterparts of those in common use. Hence no extended review is called for at this time. We are glad to note a decided improvement, as compared with the larger work, in the important particulars of paper and press-work, in spite of which, however, much of the work, and notably the two-page table of four-place logarithms, from Lee's *Tables and Formulæ*, fails of distinction for typographical excellence. T.

Franklin Institute

[*Proceedings of the stated meeting, held Wednesday, October 19, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 19, 1892.

MR. HENRY R. HEYL, in the chair.

Present, 190 members and twenty-two visitors.

Additions to membership since last report, five.

The Secretary reported the resignation, from the Committee on Science and the Arts, of Dr. George A. Koenig. An election was ordered to fill the vacancy.

Mr. Shaw nominated Mr. F. M. Jacquith; Prof. Rondinella nominated Mr. F. Lynwood Garrison. Mr. Garrison received forty-two votes, and Mr. Jacquith twelve. Mr. Garrison was accordingly declared elected.

Mr. F. E. Ives read a paper descriptive of the principles of construction and operation of the heliochromoscope, a new optical instrument of his invention for the reproduction of natural colors in photography. The speaker at the close of the meeting exhibited a photograph of a bouquet of natural flowers in the apparatus, by means of which the natural colors of the objects were very faithfully reproduced. Mr. Ives' paper was discussed by Messrs. Goldschmidt, Fullerton, Cooper and the Secretary. The paper was referred for publication.

Mr. S. Y. Buckman described an automatic tin-plate machine of his invention, and in connection therewith gave a sketch of the present state of the art of making tin plates. The machine of Mr. Buckman takes the pickled sheets (which are longer than those used in the usual method of hand-dipping), and successively and continuously performs the operations of scouring, drying, joining, fluxing and coating, and turns out the product in a continuous strip of terne plate of any desired length. (Referred for publication.)

Mr. W. E. Lockwood described the Boyer Railway Speed Recorder, and an Improved Smoke and Spark-consuming Device in Locomotive Practice.

The Secretary in his monthly report referred to the present condition of the Nicaragua Canal enterprise, and presented an abstract of the proceedings of the recent National Nicaragua Canal Convention, held at St. Louis, in which the project was cordially endorsed.

Mr. Shaw moved that the President be empowered to appoint a committee of three to confer with a similar committee to be named by the Manufacturers' Club, with the object of preparing a statement embodying the views of the two bodies for transmission to the Department of State. Carried.

Adjourned.

WM. H. WAHL, *Secretary.*